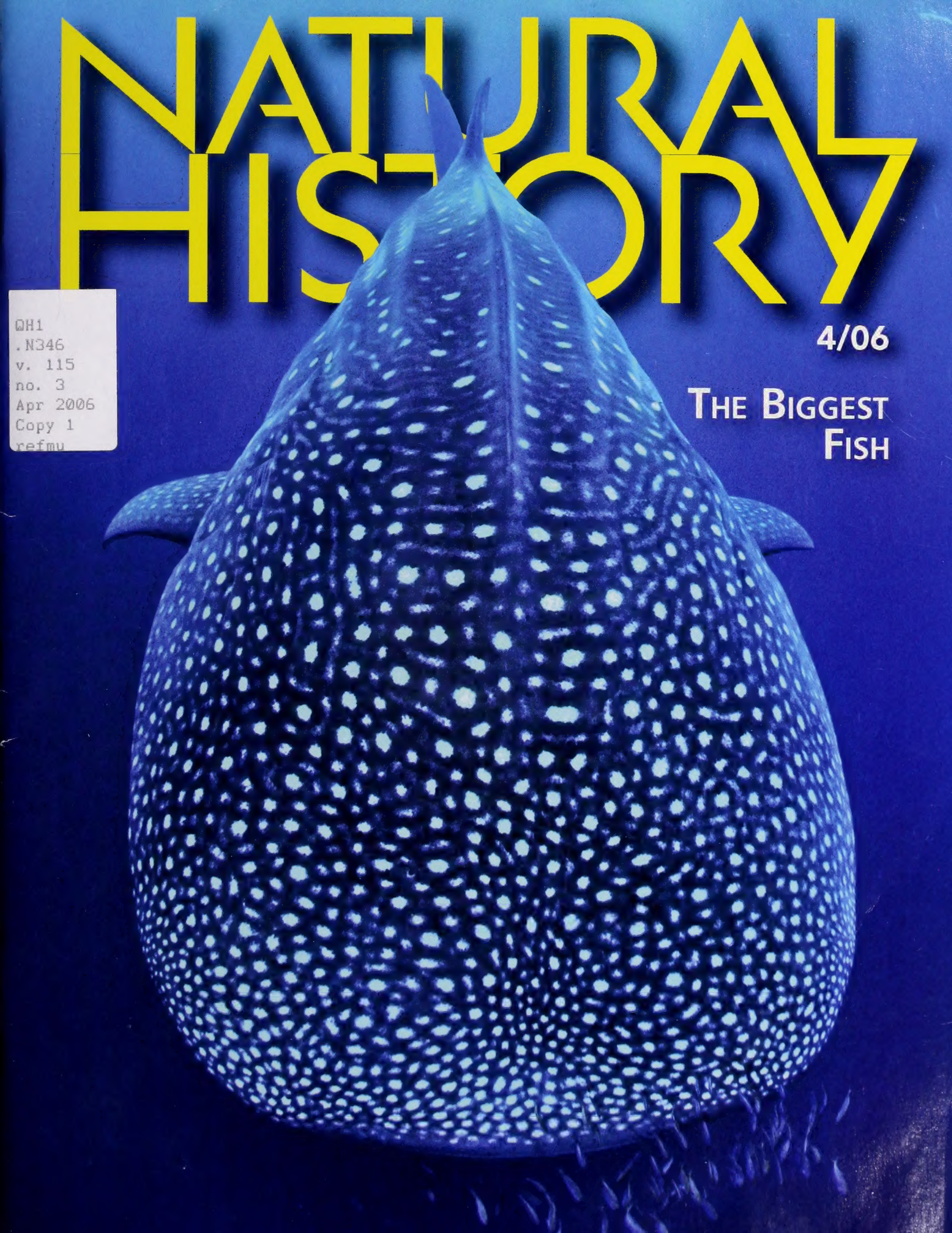
NATURAL HISTORY

4/06

THE BIGGEST FISH

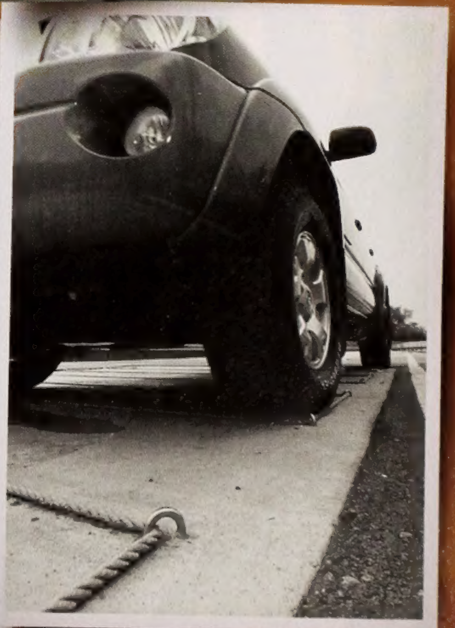


Toyota U.S. Operations
Total Jobs 386,000*
Total Investment ......$13 B

Where we go when we go back to the drawing board.

AUTOMOTIVE DESIGN IS A FIELD FOR DREAMERS. Eventually, the best dreams become real. The project ends, a new one begins, and back to the drawing board the designers go. Our Calty Design Research centers are full of such inspired dreamers. Together with the talented engineers at Toyota Technical Center (TTC), they bring these dreams to life. Yet Calty and TTC may be two of Toyota's best kept secrets.

By now, most people know that we build vehicles in the U.S.** But what they might not know is just how much we rely on Calty and TTC. They're an integral part of our investment in America, and we can't wait to see what they draw up next.



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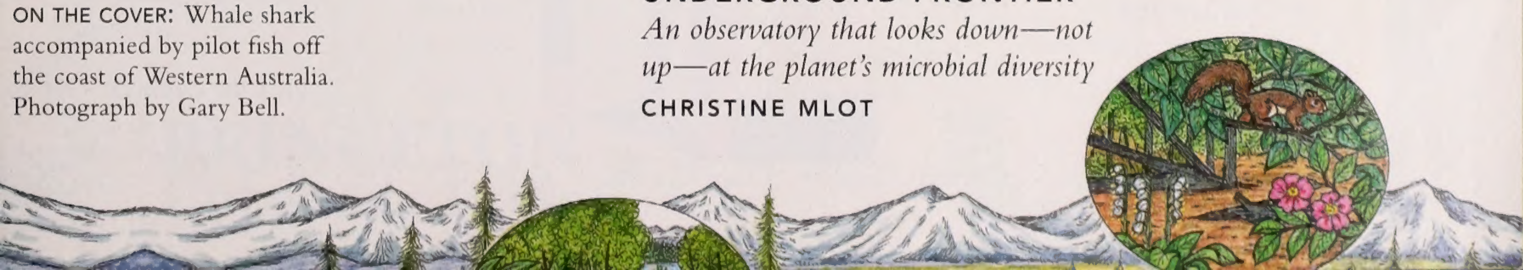
NATURAL HISTORY

APRIL 2006 VOLUME 115 NUMBER 3

FEATURES

ON THE COVER: Whale shark accompanied by pilot fish off the coast of Western Australia. Photograph by Gary Bell.



NATURAL HISTORY

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DEPARTMENTS

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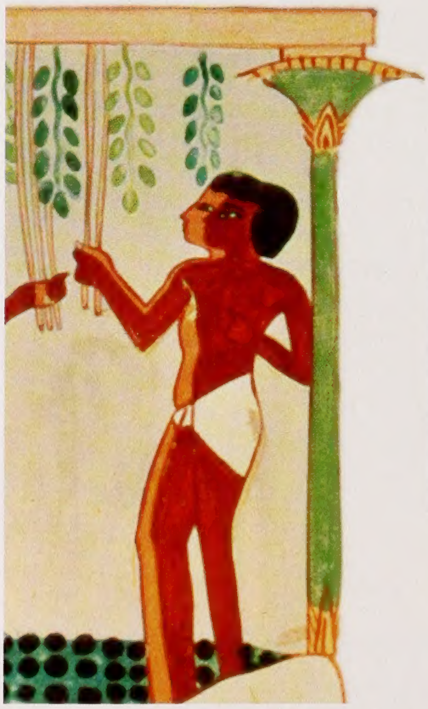

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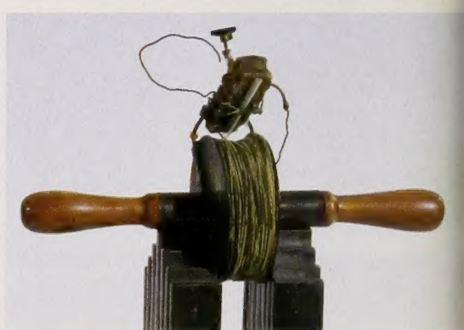

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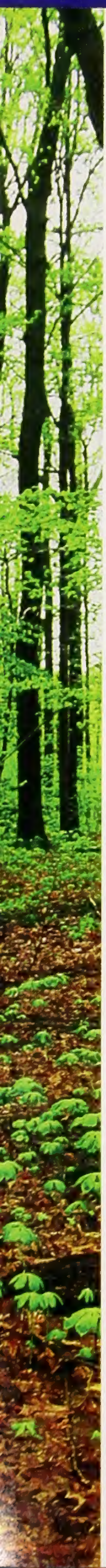

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PICTURE CREDITS: Page 10

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www.naturalhistorymag.com

THE NATURAL MOMENT

I Spy

Photograph by Simon D. Pollard

THE NATURAL MOMENT

➤ *See preceding two pages*

Enthroned on a golden flower, a female crab spider holds dominion over most visitors that stop to rest or refuel. But there's not much pomp: no intricate web, no hairy legs, no red hourglass. Instead, the spider—weighing in at about 0.005 ounce—hides in ambush among the corridors of her petal palace. Crab spiders camouflage themselves superbly, usually matching the color of their home flower. In the ultraviolet spectrum, though, the spiders may actually advertise their presence; extra UV flare apparently lures in certain insects, such as bees, that are attracted to patterned flowers.

When an unsuspecting mite or pollinating honeybee alights, the spider sinks its fangs into the victim's head or neck, injects a digestive fluid that liquefies the internal organs, and sucks the carcass dry. Nothing larger than a micron across can fit in its mouth—hence the need to liquefy. The drained hull is soon tossed or blown away, leaving a clean floral plate.

Photographer and seasoned arachnologist Simon D. Pollard sighted this crab spider *(Thomisus sp.)* in Bukit Timah, a nature reserve in Singapore. Eyes elevated on pointy projections characterize the genus *Thomisus,* and at one point Pollard could see only two little eyes—two of the spider's eight—peeping over a petal at him.

Crab spiders may be hard to spot (they see you more often than you see them), but they're not rare. More than 2,000 species exist worldwide. Remember that the next time you stop for a sniff.

—*Erin Espelie*

UP FRONT

Fish Story

Most anyone who's ever put on a mask and flippers knows the thrill of tropical reef snorkeling. You've slathered on the SPF 45, rubbed spit and seawater into your mask to clear the view, waded into the warm, clear waters off the beach, and kicked across the lagoon to the reef. The underwater world is mesmerizing, and you watch in fascination as stylish little Moorish idols skitter among the sea fans, and long, impossibly thin, almost transparent needlefish hang motionless above a growth of staghorn coral.

Then you sense a murky form, almost invisible in the distance, much larger than anything in your immediate vicinity. Brain flash: how safe are these waters, anyway? If it's a shark, do you stop to avoid the splashing that is said to attract them, or do you make a quick U-turn and head for shore? Whew! It's just a sea turtle—but, oh, what a turtle! Four feet long from stem to stern, and big enough to ride. You swim with the creature while it drifts along, allowing you within touching range, and for a moment, until it tires of the lazy pace a human swimmer can manage, you feel as if you've met a visitor from another planet. Such a close encounter can be life-changing.

Imagine, then, the frisson of coming nose to nose with a thirty-five-foot version of the leviathan that appears on our cover this month, the whale shark. Steven G. Wilson ("The Biggest Fish," page 42) doesn't need to imagine; he swims with them for a living. "I felt a jolt to my lower back," he writes, "and suddenly found myself being propelled through the water. All I could see was a whirl of spots. It took me a moment to comprehend that another, much larger whale shark had struck me with its dorsal fin and was pushing me forward."

Wilson's experience was startling, to be sure, but he was never in real danger: whale sharks are filter feeders, and nothing much bigger than krill and other puny prey are at risk of becoming food. The encounter, in any event, was a bit unusual; he was deliberately stirring up trouble by trying to dart another whale shark with an electronic tag. Most of the time, the animals are as docile as dairy cattle, and a lively ecotourism industry is building up around swimming with the creatures. On a number of reefs throughout the world—in the Yucatán of Mexico, off the coast of western Australia, in the waters off the town of Donsol, in the Philippines, and elsewhere—you too can swim with whale sharks, if you dare!

• • •

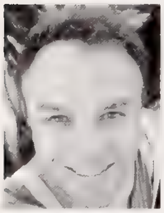
Some well-deserved recognition came to our superlative columnists recently. Neil deGrasse Tyson, our regular "Universe" columnist, will receive the prestigious American Institute of Physics Science Writing Award this May, for best article by a scientist, for his column "In the Beginning" (September 2003).

Joe Rao, our long-time "Sky" columnist ("The Sky in April," page 74) and the weeknight TV weatherman on News 12 Westchester, has been nominated for a New York Emmy for On-Camera Talent in the weathercasting category.

Congratulations to both! —PETER BROWN

CONTRIBUTORS

Spotting a spider, even one hiding between the petals of a flower, has become second nature to arachnologist **SIMON D. POLLARD** ("I Spy," page 4). After earning his Ph.D. from the University of Canterbury in Christchurch, New Zealand, Pollard began studying how flower-dwelling crab spiders drink nectar. Since then, his research interests have included jumping spiders in Borneo and the Philippines, water striders in China, and crab spiders that live and commit suicide in pitcher plants. He is the author of several earlier articles in *Natural History*, and his work has also appeared widely in other publications. Pollard is curator of invertebrate zoology at the Canterbury Museum in Christchurch.



STEVEN G. WILSON ("The Biggest Fish," page 42) earned his doctorate from the University of Western Australia in 2001 for studies on the physical and biological factors that affect the aggregation of whale sharks at Ningaloo Reef, off the coast of Western Australia. Wilson had earlier worked as a high school biology teacher, dive-boat captain, and pearl diver. His research focuses on the migratory movements and vertical behavior of large pelagic fishes: tunas, billfishes, and sharks. He holds an appointment as a postdoctoral research scientist at Hubbs–SeaWorld Research Institute in San Diego, California. This May, Wilson will return to Ningaloo Reef to continue his studies of the whale shark.

Naturalist and artist **STEPHEN CHRISTOPHER QUINN** ("The Worlds behind the Glass," page 48) joined the staff of the American Museum of Natural History in 1974. He apprenticed under masters of diorama art Raymond deLucia, Robert Kane, and David J. Schwendeman. His first assignment was as a foreground artist for the wood stork diorama in the Leonard C. Sanford Hall of North American Birds in the museum. He is now senior project manager for exhibitions at the museum, where he oversees the creation of new dioramas as well as the conservation and restoration of existing ones. Quinn illustrated the book *What Color Is That Dinosaur?* by Lowell Dingus (Millbrook Press, 1994).

CHRISTINE MLOT ("Alaska's Underground Frontier," page 54) studied microbiology as an undergraduate, then switched fields to do graduate study in science communication. She has written for such magazines as *Science* and *Science News.* Recently she returned to her microbiology roots as a reporter, doing bench work in Jo Handelsman's plant-pathology laboratory at the University of Wisconsin–Madison. The lab work combines two of her favorite topics, Alaska and microbial diversity. Mlot was awarded a Knight Science Journalism Fellowship, and she has taught writing at the University of Wisconsin. She is a contributing editor for *Nature Conservancy* magazine.

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Weevil Evil

Robert W. Jones's fascinating article on the boll weevil, "March of the Weevils" [2/06], recalls the lines from an old blues song describing with chilling effect what the weevil did to African-American farmers in the South:

Boll weevil told the farmer,
"You'll need no Ford machine,
I'll eat up all your cotton,
Can't buy no gasoline."

I don't see no water,
But I'm about to drown,
I don't see no fire,
But I'm a-burnin' down.

In my work on Maya plant use and agriculture in the Mexican state of Quintana Roo, I found that Maya in isolated villages were growing strange (often very large) and ancient varieties of cotton, usually under the name "snake cotton" (*tamankaan* in Maya). Those local varieties of cotton never had a bit of weevil damage. They should be sought out.

Eugene N. Anderson
University of California
Riverside, California

Robert Jones's article presents the history of the boll weevil invasion of the U.S. Cotton Belt with great clarity. His presentation of one of the sidelights to the story was particularly lucid—the seemingly esoteric questions concerning the taxonomy and classification of boll weevils and their host plants. The answers to those questions, which have added to biologists' knowledge about the life history and evolutionary history of the weevil, have also led to new avenues of research in the development of possible control measures. For example, investigators have discovered that parasites might be able to replace pesticide sprays in exterminating the weevil.

Paul A. Fryxell
Rancho Santa Ana Botanic Garden
Claremont, California

ROBERT W. JONES REPLIES: Eugene N. Anderson's intriguing comment pertains to the larger question of whether the pre-Columbian cultures of Mesoamerica had to deal with the boll weevil. Some investigators maintain that the weevil is a recent pest, having switched from its wild host, *Hampea,* only shortly before invading the United States. But the discovery of a weevil in a cotton boll from Central Mexico dating from A.D. 900 indicates that the weevil was a pest of cultivated cotton long before it appeared in the U.S. Yet indigenous cultures were clearly able to grow sizable quantities of cotton, which suggests they had a variety of tactics and, as Mr. Anderson proposes, resis-

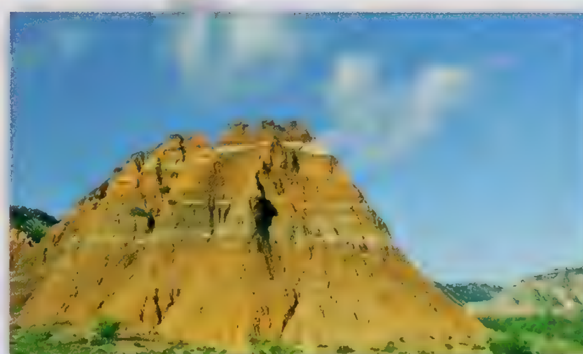
(Continued on page 75)

Barrett & MacKay

An island of tides
red sandstone cliffs

New Mexico Department of Tourism

wavelike sands
bluebonnets & birds



the world's oldest civilizations
a Mediterranean cruise
. . . and more

DISTINCTIVE DESTINATIONS

SPRING 2006

NEW BRUNSWICK A WORLD OF WONDER!

IT HAPPENS HERE IN NEW BRUNSWICK, CANADA'S BAY OF FUNDY, ONE OF THE MARINE WONDERS OF THE WORLD.

FIND YOURSELF AMONG THREE-HUNDRED-million-year-old plant fossils embedded in some of the oldest visible rock on Earth. The natural wonders here are like nothing you've seen before. The world's highest tides . . . they rise to over 48ft. (14 m) in some places. Falls reverse themselves and start to flow backward, and powerful tides sculpt the landscape. At low tide, spelunk through caves and touch the base of giant rocks reaching up from the ocean floor; at high tide, kayak around miniature islands. That's just the tip of the many natural wonders in New Brunswick.

With 100 billion tons of seawater rushing in and out of the bay twice a day, bizarre things happen.

There's diverse landscape here. Extending northeast from the Bay of Fundy are some of Canada's most popular swimming beaches with some of the warmest salt water north of Virginia. Here you'll find the world's second longest sandbar, and one of the continent's last remaining white sand dunes at the Irving Eco-Centre, La Dune de Bouctouche. On the northern portion of the province lies the Baie des Chaleurs, named one of the world's most beautiful bays.

Along the interior of the province, rivers and waterways account for some of the best canoeing and kayaking to be had. Tour the St. John River Valley for 400 km (248 mi.) of pure inspiration. Witness the change in landscape from the calm of lush, green valleys to the whitewater rush of the Grand Falls Gorge. The world-renowned Miramichi River beckons you to cast a line with some of Canada's best salmon fishing, and the beautiful Restigouche, St. Croix, and Kedgwick rivers will let you canoe for endless days along unspoiled wilderness. Be awed by the untouched vastness of some of the oldest mountains on the planet. Hiking possibilities abound throughout the province; for a spectacular view, climb some of the mountains, which are part of the Appalachian Range.

With waterfowl parks and designated wetlands, New Brunswick is a true birdwatching paradise. Up to 95 percent of the world's sandpipers depend upon the Bay of Fundy mudflats for their survival. Prepare to be awestruck when they are airborne; coordinating their movements, the birds resemble a school of fish in flight. Not to be missed is the Grand Manan archipelago with eagles, puffins, and ospreys. On the eastern tip of the

Clockwise from top left: The Hopewell Rocks, Hopewell Cape; Atlantic puffin; Chaleur Bay; Appalachian Range; Grand Falls Gorge, Grand Falls/Grand-Sault; Fundy National Park of Canada, Alma

province, the eco-friendly Cape Jourimain Nature Centre is also an important stopover for migratory birds and offers an educational look at history, art, and green technology systems. Whether seeking forest-dwelling creatures while on a hike, spotting seals from a kayak or whales from a boat, you're sure to find an outdoor wildlife adventure in New Brunswick, Canada!

From the phenomenal Fundy tides to the top of the Maritimes, New Brunswick welcomes you to discover all of its island retreats, coastal crags, horticultural wonders, and panoramic mountainous views. Take your taste buds on a tour of the most succulent seafood and down-home cooking. Keep an eye out for the colorful flags that adorn lighthouses and boats all along the Acadian coast, a symbol for a lively culture that's ready to take you by the hand. The whole northeastern coast runs through the heart of Acadia. Take a walk back in time at the Village Historique Acadien for a lively interpretation of the fascinating history of the Acadians, and, for a toe-tapping good time, visit the island of legends and laughs at Le Pays de la Sagouine.

Unique shops in our hometowns . . . galleries in our cosmopolitan cities . . . incredible values. That legendary East Coast hospitality will greet you down every street with the coziest B&Bs and inns to welcome you at the end of the day.

It's a world of natural wonder and it's all waiting for you here in New Brunswick, Canada.

started here on the ocean floor.

St. John River Valley

Chaleur Bay

City of Fredericton

When we got to Chaleur Bay, we could see why it won such a distinction. **One of the world's most beautiful bays.** It was breathtaking, and so were the Appalachians nearby. We followed the mighty meandering **St. John River**—from its tranquil solitude to its raging tidal rapids. It led us between the towering walls of the Grand Falls Gorge, lush riverside valleys, and covered bridges as old as the river is long. There was something spectacular around every bend... **400 kilometres (248 mi.) of pure inspiration.**

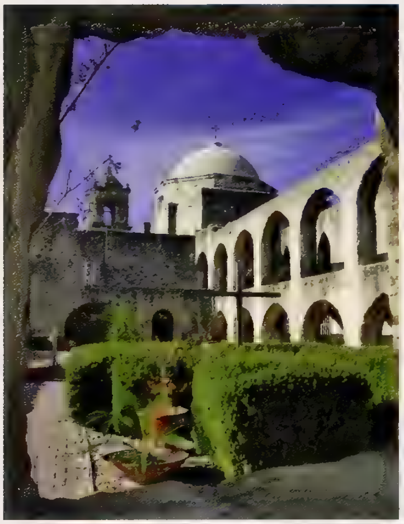
There literally were no small wonders—from the World's Highest Tides and whales breaching before our eyes, to **saltwater beaches that stretch for miles.** We were charmed by the hometowns, the lively Acadian culture and succulent seafood. We were visitors, but we felt like we had lived here all our lives. It was all here, **next door, in New Brunswick, Canada!**

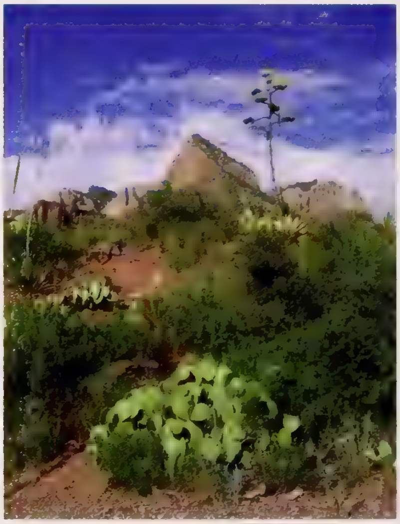
1 800 561-0123 www.TourismNewBrunswick.ca Check out our neighbours at www.TourismNewBrunswick.ca/Neighbours

Contact us for your **FREE DVD** and **FREE 2006 Vacation Planning Kit** and discover awesome vacation ideas, great value and a world of Natural Wonder.

TEXAS

APRIL, WHEN THE LONE STAR STATE IS ABLOOM WITH WILDFLOWERS, IS A PERFECT TIME TO ENJOY ITS CITIES OR DO SOME SPECTACULAR BIRDWATCHING.





Top left: Mission San Jose, founded in 1720, is part of the San Antonio Missions National Historical Park; top right: along the Pine Canyon Trail in the Chisos Mountains.

YOUR VISIT TO TEXAS MAY START OUT IN Dallas, a thriving metropolis that began with a single log cabin built in 1841, or in Houston, the state's largest city, first settled in 1836. In Austin, the Lady Bird Johnson Wildflower Center, dedicated to native plants, is spectacular this month. All of these sophisticated cities will keep you busy with a plethora of historical and cultural attractions including many fine museums (be sure not to miss the Natural History Museum in Dallas). But in Texas, nature is never far away.

As you head east from Houston toward the island of Galveston, about an hour away, stop by the Armand Bayou Nature Center, one of largest urban wildlife and wilderness preserves in the country. Home to bison, raptors, and reptiles, the center comprises three ecosystems—bayou, forest, and

THE STATE

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prairie—as well as butterfly gardens and a typically Texan farm from the 1800s. In Corpus Christi, the center of Texas's Gulf Coast region, visit the Texas State Aquarium. Don't miss Port Aransas, which claims to be one of the top twelve birding sites in the country. In the spring, watch migrating hummingbirds, which are attracted to these wetlands, as well as wading and shorebirds. South of Port Aransas, you'll find Mustang Island, where acres of sand dunes, sea oats, and beach morning glory combine to offer the best of seaside camping, surfing, fishing, swimming, and shell collecting.

With over 600 bird species, Texas may well be the birding capital of the United States.

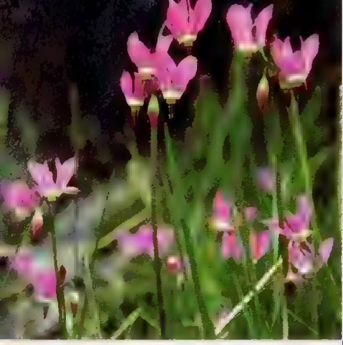
In the lower Rio Grande Valley, just north of Mexico, visit the World Birding Center, headquartered in the Bentsen-Rio Grande Valley State Park. At Bentsen, you'll see birds found nowhere else in the United States but deepest South Texas, as well as rare visitors from across the Rio Grande. Green Jays and Plain Chachalacas congregate regularly in this floodplain forest, and flocks of migrating Swainson's and Broad-winged hawks are common in spring and fall. Bentsen is only one of nine sites that make up the center, whose habitats range from dry chaparral brush and verdant riverside thickets to freshwater marshes and coastal wetlands. South Padre Island is the first landfall for birds making the arduous Gulf crossing from southern Mexico and northern Central America. In spring, you'll find warblers, tanagers, orioles, and thrushes in wooded areas and shorebirds and waterfowl in the wetlands; with luck, spot endangered species such as Piping Plover and Peregrine Falcon.

For more information and to order a FREE Texas State Travel Guide, call 1-800-8888-TEX, Ext. 3860 or visit TravelTex.com.

Follow the Official Bluebonnet Trail, which stars the State flower, in bloom this month. Acres of this native flower were planted along Texas highways, thanks to Lady Bird Johnson

TEXAS

It's like a whole other country



New Mexico Department of Tourism

NEW MEXICO

FROM HOT SPRINGS HIGH IN THE MOUNTAINS TO THE WORLD'S LARGEST DEPOSIT OF GYPSUM SAND, NEW MEXICO IS INTRIGUING TO THOSE WITH A PASSION FOR NATURAL HISTORY.

NEW MEXICO IS FAMOUS FOR ITS ANCIENT past. It is where dinosaurs once roamed, and where the Anasazi built their unique cliff-side dwellings, whose ruins are preserved at the Mesa Verde National Park. But the state is also worth visiting simply for its natural beauty.

Learn about caving first-hand at the Carlsbad Caverns National Park. Known for their gigantic and often bizarre formations, the caves formed some 250 million years ago when the region was an inland sea. Take a ranger-led tour or explore on your own, but don't miss Lechuguilla, the nation's deepest limestone cave, or the Big Room, as large as eight football fields. At El Malpais National Monument, would-be volcanologists can explore underground lava flows formed 115,000 to 2,000 years ago. Hike on an established trail or go out on your own amid the volcanic features that dominate the landscape, including cinder cones, pressure ridges, and complex lava tube systems. Volcano buffs also will enjoy the Capulin Volcano National Monument; follow the two-mile road to the rim for spectacular views of the volcanic landscape.

With an average of 310 days of sunshine, New Mexico is an outdoors paradise for nature lovers.

At the northern end of the Chihuahan Desert, the White Sands National Monument comprises almost 300 square miles of glistening, wavelike dunes of gypsym sand. The dunes are always moving and changing their appearance, making them fascinating to photographers as well as nature lovers. They are home to a few plants and animals, many of the latter camouflaged in white, that can survive the harsh environment. Take an eight-mile drive from the visitor center to the heart of the monument, or a one-mile hike along the Dune Life Nature Trail. In contrast to White Sands, the Bisti Badlands are almost unknown and little visited—which makes then all the more attractive to those seeking solitude in the high desert. The Bisti's fragile sandstone formations, colorful and undulating mounds, and unusual eroded rocks make up a landscape that sometimes feels like it's on another planet.

For more information, please visit www.newmexico.org.

New Mexico Department of Tourism

Top: Field of wildflowers; northern New Mexico landscape. Left: the steam-era Cumbres and Toltec Scenic Railroad. Right: unusual sand formations at the Bisti Badlands.

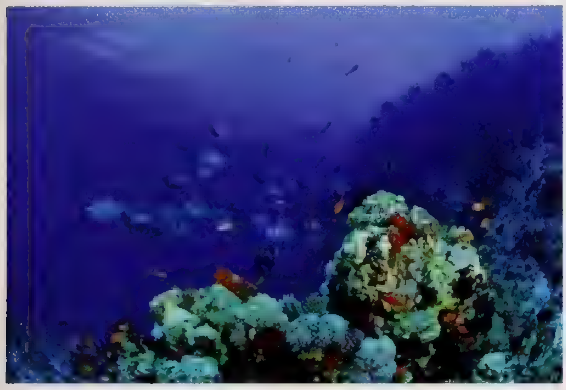
BUFFALO BILL'S CODY/YELLOWSTONE COUNTRY

PARK COUNTY, IN NORTHWEST WYOMING, is Buffalo Bill's Cody/Yellowstone Country. In 1896 Col. William F. "Buffalo Bill" Cody founded Cody, the heart of this county, which still maintains a true Western flavor. To learn about Buffalo Bill and local history, take Cody's trolley tour. Cody is the eastern gateway to Yellowstone National Park, the nation's first national park (1872); the county also includes Shoshone National Forest, our first national forest (1891). Wildlife is plentiful: buffalo, deer, moose, bighorn sheep, elk, grizzly bear, black bear, and eagles are easily spotted in the grass prairies, mountain slopes, and wildflower meadows. Try your hand at fly-fishing on spectacular trout streams; float through the rapids of the Shoshone River Canyon; rock-climb the steep granite cliffs; hike or horseback-ride on the Cody PathWays, a system of paths and trails. Stay at the Victorian-style Irma Hotel, founded by Buffalo Bill in 1902 and named after his youngest daughter, or the Pahaska Teepee Lodge, which he founded in 1904 in the heart of the forest; both are on the National Register of Historic Places. Cody also has many museums devoted to Buffalo Bill, the Plains Indians, firearms, Western art, and natural history. The Buffalo Bill Dam, completed in 1920, was one of the first concrete dams in the country and transformed the area's landscape. Don't miss Cody Nite Rodeo or the Branson-style Cowboy Music Revue. For more information, visit www.yellowstonecountry.org.

EGYPT

EGYPT IS ONE OF THE WORLD'S OLDEST CIVILIZATIONS — ITS HISTORY GOES BACK SOME 5,000 YEARS — AND PROBABLY ONE OF THE OLDEST VACATION DESTINATIONS, TOO.

ITS MOST FAMOUS SITE IS PROBABLY THE Great Pyramids of Giza (including the Great Sphinx and the pyramid of Khufu), but there are about a hundred other pyramids in the country, and almost all are grouped near Cairo. In addition to monuments from the era of the pharaohs, Egypt has a wealth of mosques, ancient Christian churches, and Jewish temples, testifying to its importance in the birth of these religions. Luxor, which has been called an open-air museum, is famed for its temples. The Temple of Karnak (just north of Luxor) is still the world's largest religious structure, and the Temple of Luxor, built by Amenhotep III and Ramses III, housed the festivals of Thebes. In between these famous sites, take a trek in the Western Desert, perhaps to the oasis of Fayuum, about 100 kilometers southwest of Cairo (an oasis is a depression in the desert where you'll find trees, springs and wells, and a year-round pleasant climate). Visit the beaches of the Red Sea, which has become known for its diving; or take a traditional cruise down the Nile River, heading south from Cairo, for an all-encompassing view of the country.

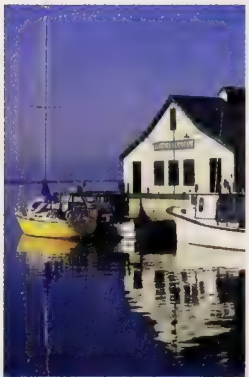


For more information, visit www.egypttourism.org.

Left: Diving in the Red Sea.
Top: Horus Temple at Edfu

PRINCE EDWARD ISLAND

WHAT IF THE WORLD HAD BEEN TO PRINCE EDWARD ISLAND? THIS GENTLE ISLAND OFF CANADA'S EAST COAST IS A SPECIAL PLACE WHERE ROLLING FARM FIELDS SPILL INTO THE SEA AND THE BRILLIANT COLORS OF THE LANDSCAPE GLOW IN OCEAN AIR.



Photos: John Sylvester

Top: Victoria; Green Gables in Cavendish; West Point Lighthouse

A VISIT TO OUR ISLAND REMINDS YOU OF the important things in life; it is a place where strangers are friendly and people have a sense of perspective. If the world had been to Prince Edward Island, we think the world would be a better place.

Imagine a complete holiday destination all tied up in one neat, compact, green package, a smile-shaped slice of paradise—this is our gentle island.

This 180-mile-long crescent of farm fields, winding rivers, and sandy beaches contains all you need to fill a week's worth of memories.

Prince Edward Island is geographically and topographically seductive, with acres of rolling pasture, potato fields, and woodlots, stitched together by country lanes and winding rivers, all fringed by miles of coastline made up of alternating red sandstone cliffs and white sandy beaches.

Touring Canada's smallest province by car can mean following coastal drives in and out of tiny fishing villages; exploring tree-lined, red clay roads through farms and woodlots; or plotting a course that takes you from warm ocean waters to top-class golf courses, antique shops to museums, or theaters to community concerts.

Start in the capital city of Charlottetown, where Canada was born; the event is commemorated at Founders Hall and the national historic site of Province House. Anne of Green Gables was born here too, and almost everyone wants to visit the Green Gables site in Cavendish and see the musical that has been on stage at the Charlottetown Festival for 42 seasons now.

Touring the island by bicycle becomes almost irresistible once you've reviewed the network of trails and quiet back roads that crisscross the province. A cycling trail that connects one end of the crescent-shaped province to the other invites ambitious cyclists to take on a tip-to-tip Confederation Trail adventure. If land-based touring is just too dry, think of joining a sea kayak expedition. There are tour companies that will guide you from inn to inn, or to special deserted islands just off the coast. Paddling all day in the salty air develops an appetite and you can count on delicious evening meals of fresh island seafood, whether served at the table of a country inn, or over an open fire on a quiet beach.

Save time for basking or strolling on the miles of deserted white and pink sand beaches followed by an evening at the theater, local pub, or concert of traditional music in a community hall. You will fall asleep listening to the waves mingled with echoes of Celtic music.

For more information visit www.gentleisland.com or telephone 1-800-463-4PEI.

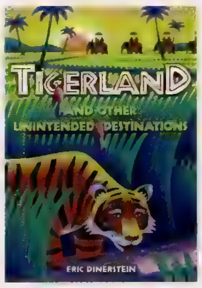
What if the world had been to Prince Edward Island?
People stuck in traffic would wave their whole hand at each other and not just one finger.
There's a place where things are different. A place where the road is open and there are no strangers, just friends you have yet to meet. We invite you to our Island where the point of every journey is never just a destination but the journey itself.
Prince Edward Island
The Gentle Island
For your Island Guide, visit gentleisland.com/leonard or call 1-800-463-4PEI and ask for Leonard.
Check out our neighbours at gentleisland.com/neighbours
Canada

ORIENT LINES

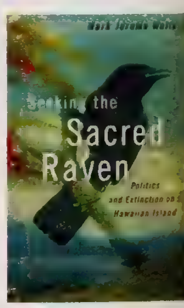
ORIENT LINES, THE DESTINATION CRUISE specialist, offers extraordinary vacations to every part of the world. Its flagship, the *Marco Polo*, carries over 800 passengers on journeys of luxury and discovery; every modern convenience is provided, and guest lecturers are on board to enhance the experience. In spring and fall, the *Marco Polo* visits the Mediterranean (primarily Italy) and the Greek Isles, with journeys ranging from a 10-day jaunt from Athens to Venice, to a 26-day Grand Mediterranean Discovery from Athens to Barcelona. For a grand and leisurely experience, take a classic transatlantic cruise, from Montego Bay to Barcelona or to Athens. In the summer, cruises focus on Britain and Scandinavia, the Baltic capitals, St. Petersburg, and the Norwegian fjords, with two nights in hotels in London or Copenhagen. Orient also offers cruises akin to the Grand Tours of old, including a 36-day Great Cities of Western & Northern Europe from Rome to Stockholm, and a 38-day Journey to the Top of the World from London to Copenhagen. In winter, explore South America, from the fjords of Chile to the rain forests of the Amazon, on three different cruises; take a 15-day tour of Central America; or journey to Antarctica. For more information, visit www.orientlines.com.

New books focus on the history of archeological tourism, maps of the U.S., exploring the natural world, and the fate of a sacred Hawaiian bird

ISLAND PRESS



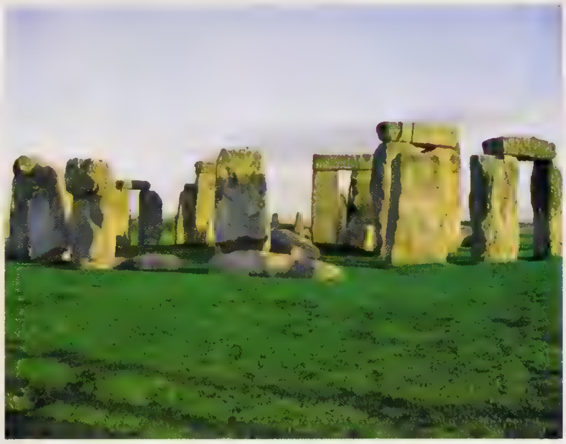
WHILE IN FILM SCHOOL, ERIC DINERSTEIN—WHO BY his own admission was "training to be the anti-Thoreau"—was captivated by a little green heron. He spent the next 30 years exploring the natural world, traveling to all ends of the Earth to discover and protect wildlife. Now the chief scientist at the World Wildlife Fund-US, Dinerstein recounts his explorations of the wildlife and landscapes he encountered—from the forests of Nepal to the Galapagos Islands to the eastern plains of Montana—in *Tigerland and Other Unintended Destinations.*



Seeking the Sacred Raven, by Mark Jerome Walters, tracks the fate of the 'Alala, a sacred Hawaiian bird and member of the raven family. Walters explores the role of the bird in Hawaiian culture and its decline to near-extinction; once numbering in the thousands, today only 50 'Alala survive in captivity. He travels through the cloud forests of Mauna Loa interviewing biologists and others to assemble the story of the sacred bird and the people who battled to save it. Walters captures not only the many dimensions of species loss but also the story of the Hawaiian people and culture, from the ancient Polynesian settlers, to Captain Cook, to the would-be saviors of the 'Alala in the 1990s.

Both these titles are published by Island Press, which issues approximately 40 new titles per year on topics ranging from biodiversity and land use to forest management, agriculture, marine science, climate change, and energy. For more information about this innovative publisher, visit www.islandpress.org.

OXFORD UNIVERSITY PRESS



OXFORD UNIVERSITY PRESS is the world's largest university press. Its publications are written at a variety of levels, for a wide range of audiences in almost every academic discipline. Brian Fagan's *From Stonehenge to Samarkand* is a history of our fascination with antiquity, captured in the writings of noted archaeological tourists, from Herodotus to Rose Macaulay. Fagan, a renowned scholar and author, explores our irresistible impulse to visit strange lands in search of lost cities and forgotten monuments. His history features excerpts from earlier writings: Herodotus describes the construction of Babylon, Gibbon wanders through the ruins of the Roman Forum, Flaubert watches the sunrise from atop an Egyptian pyramid, and more.

The *Atlas of the United States* offers a closer look at the oldest, richest, and most populous country on the continent, with newly drawn maps and instructive charts and graphs. The heart of this comprehensive volume is a unique thematic section covering topics ranging from environmental change to religious practice, and indigenous peoples to migration patterns. With hundreds of maps rendering every region from Barrow, Alaska to Venice, Florida in layer-colored contours, this atlas is the United States as it hasn't been seen before.

TRAVEL TIPS

BEFORE YOU EMBARK ON YOUR TRIP to a Distinctive Destination, spend some time doing a bit of on-line research. For domestic travel, try the websites of the individual counties or states that you're visiting for a plethora of information, including an up-to-date calendar of events, fairs, and festivals; specialized local attractions that might never have made it into your guidebook; local birding lists and viewing spots; biking trails, hiking maps, and much more. There is nothing like attending a local event, off the usual tourist path, to enhance your understanding of the destination.

For international travel, check out the sites of the individual countries, which almost always have sections on ecotourism and nature traveling. Visit http://travel.state.gov, the website of the U.S. Department of State Bureau of Consular Affairs, for a wealth of information ranging from tips for traveling abroad, consular information sheets, and other vital information to plan your trip. Your airline's website will list maximum sizes and weights for your luggage and other useful information.

Happy traveling!

SOME NATURAL WONDERS IN NEWFOUNDLAND AND LABRADOR

NEWFOUNDLAND AND LABRADOR IS AN EDGY PLACE. LOCATED ON THE EASTERN EDGE OF NORTH AMERICA, IT'S WHERE BIRDS, BERGS, AND WHALES SHARE SPACE IN THE OCEAN.

WHALES MIGRATE NORTH AS BERGS DRIFT south, their paths crossing beneath the gaze of millions of seabirds. Sometimes you can see all three at once, either from shore or from a tour boat. If you're lucky. Ever smelled the air from a 10,000-year-old berg? It's so old it's fresh.

On land, keep an eye out for moose because there are 125,000 of them. Their cousins come in great numbers, too, in Labrador where there are 450,000 barren ground caribou.

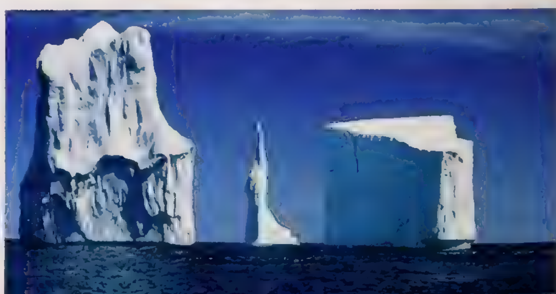
There are rare orchids, including one that grows nowhere else, the Burnt Cape Cinquefoil.

Bald eagles might be the most sought-after raptor, and you'll find them nesting in Terra Nova National Park, among other places. Because of its location on migration flyways, Newfoundland and Labrador is a good place to spot rarities, especially on headlands, those edges of the earth.

This place is edgy in another way. Both land and sea straddle the boundaries of plant colonies. In some places, it is the southernmost edge of northern alpine plants; and in other, the northernmost reach of underwater species.

And because Newfoundland and Labrador is only a few hours by air from major centers, it's easy to get here. When you do, Witless Bay Ecological Reserve, with its puffins and humpbacks, is half an hour from St. John's and is patrolled by half a dozen tour boats. The most accessible seabird colony in eastern Canada is Cape St. Mary's Ecological Reserve where thousands of golden-headed Northern Gannets nest atop a sea stack 50 feet from a clifftop viewing point.

Gros Morne National Park, on the west coast of the Island of Newfoundland, is a UNESCO World Heritage Site. It's one of the great natural wonders of the world, with its fjords, rare rocks, ancient mountains, and inspiring landscapes. It will change you.



Top: You'll find the largest barren ground caribou herd in the world in Labrador; Right: 10,000-year-old icebergs drift by the coast of Newfoundland and Labrador in spring and early summer.

SAMPLINGS

Cloudy Skies

Cars, planes, trucks, and trains are infamous air polluters, but ships are often overlooked. Yet increased shipping in recent decades has led to a dramatic rise in ships' fuel consumption, which more than quadrupled between 1950 and 2001. Now, the effects of the ships' correspondingly increased emissions have been detected in clouds. Hint: they aren't wisps of black soot.

Cloud droplets form around airborne particles, which engines and factories that lack adequate filters emit in abundance. More droplets make for denser, higher clouds. Because dense, polluted clouds reflect more light, and higher clouds have cooler tops than normal clouds do, the effects of pollution can be measured by visible-light and infrared sensors aboard satellites.

Abhay Devasthale, a remote-sensing specialist at the University of Hamburg in Germany, and two colleagues published data that highlight ship pollution in the air above the English Channel and its three dingiest harbors. Between 1997 and 2002, Devasthale reports, clouds there became about 1.5 percent more reflective, and the temperature of their tops dropped by about three degrees Fahrenheit. Meanwhile, over nearby inland areas the trend was reversed. Thus, despite successful European efforts to reduce land-based emissions, ship exhaust remains a troubling source of air pollution. (*Geophysical Research Letters* 33:L02811, 2006)

—*Stéphan Reebs*

Ship pollutes the air in Ushuaia, at the southern tip of Argentina.

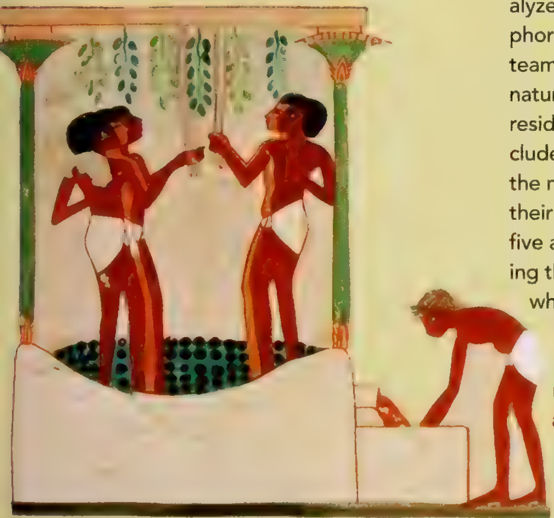
A Very Dry White

The ancient Egyptians loved their wine. They buried their dead with wine-filled amphorae, or clay vessels, to ensure a comfortable afterlife, and they painted scenes of viticulture and winemaking on the walls of tombs. But what varieties did they enjoy? Written records and the dark color of tomb-wall grapes suggest they drank reds. But now there's evidence that whites were popular, too.

Maria Rosa Guasch-Jané, an Egyptologist, and Rosa M. Lamuela-Raventós, a food and nutrition scientist, both at the University of Barcelona, Spain, and their colleagues analyzed residues in six of the twenty-six amphorae from King Tutankhamun's tomb. The team detected tartaric acid, which occurs naturally only in grapes, in each of the residues. Dark residue in one amphora included syringic acid, which is derived from the main pigment that gives red grapes their color. Yellowish residues in the other five amphorae lacked syringic acid, suggesting they were probably the remnants of white wines.

The ancient Egyptians appear to have valued white wine as much as red. King Tut was buried with three amphorae near his sarcophagus; two of them held red wine and the third held white. (*Journal of Archaeological Science*, forthcoming)

—*Rebecca Kessler*



Egyptian winemaking, tomb painting, 1400 B.C.

Millipede Soccer

For the coati, a small mammal that ranges from the southwestern United States to South America, few snacks are more tempting than a juicy millipede. But something unpleasant stands in the way of an easy meal: evolution has equipped the millipede with chemical defenses that deter most predators. What's a coati to do? On first encounter, it rolls the many-legged arthropod between its front paws. The millipede responds in a panic, pumping out poisons as fast as it can. Soon, though, the supply of poisons is exhausted. Then, the coati simply drags the millipede through the soil, effectively wiping off the toxins. Voilà! It's snack time.

But there's more. According to a study led by Paul J. Weldon, a biologist at the Smithsonian Institution in Front Royal, Virginia, the noxious chemicals secreted by irritated millipedes actually trigger the coati's prey-rolling behavior. The coati's response is so "hard wired" that even a stick dipped in the millipede's defensive chemicals elicits the behavior. The coati has won this evolutionary arms race in more ways than one. (*Naturwissenschaften* **93**:14–6, 2006)

—*Nick W. Atkinson*

Coati plays with its food.

Made in India

A dizzying variety of cultures and languages flourish among India's billion-plus residents. Did the differences arise among the descendants of that nation's first settlers, who likely arrived in South Asia from Africa more than 40,000 years ago, or do they reflect subsequent waves of immigration? Northern people often share cultural practices such as farming, social castes, and Indo-European languages, which has prompted speculation that their ancestors immigrated in a more recent wave, possibly from West or Central Asia.

But several studies have shown scant variation in the mitochondrial DNA of Indians throughout the nation, and little similarity to populations outside South Asia. That suggests a single, early origin. Mitochondrial DNA is passed only from mother to child, however, and so, strictly speaking, what the studies have shown is that only one wave of female immigrants entered prehistoric India. The DNA of the Y chromosome, passed from father to son, can help show whether there was an influx of men.

A team of geneticists led by Sanghamitra Sahoo and V.K. Kashyap from the National DNA Analysis Centre in Calcutta examined the Y chromosomes of men throughout India. They, too, found little genetic evidence for a second wave of immigrants to India. Only one small group, Tibeto-Burman–language speakers in the northeast, seemed to have arrived relatively recently, probably from East Asia. The Indo-European–language speakers, by contrast, appear to be native born. By and large, then, India's cultural differences probably evolved within a somewhat genetically isolated population. (*PNAS* **103**:843–8, 2006) —*S.R.*

Indian men: the Ys that bind?

At a crux in the family tree

Time Dilation

Like every other living thing, we humans and our nearest relatives, the chimpanzees, have "junk" DNA. It probably doesn't code for anything functional, but it sure is useful to evolutionary biologists. Because mutations within noncoding DNA are not exposed to the rigors of natural selection, they accumulate. And because they tend to arise at regular intervals, they are useful as "molecular clocks." Knowing the mutation rate and the number of genetic differences between two species, evolutionary biologists can estimate when the species diverged: some 6 million years ago, in the case of humans and chimpanzees.

In the geologically recent past, however, human generations have been longer than those of our cousins: about twenty years, on average, compared to the chimpanzee's fifteen. Now a team of geneticists has determined that the difference in generation span has led to different rates of mutation in noncoding DNA.

Navin Elango and Soojin V. Yi, both geneticists at the Georgia Institute of Technology in Atlanta, and their colleagues conducted one of the largest and most precise comparisons ever made between the noncoding DNA of humans and our closest relatives. According to their findings, the human molecular clock does indeed tick slower than that of chimpanzees, which in turn runs slower than the clocks of gorillas and orangutans. Yet the differences are so small that longer generations among humans likely evolved just a million years ago. (*PNAS* **103**:1370–5, 2006) —*S.R.*

Ocean Genome

Microscopic life thrives in the open ocean, where it plays a key role in the complex flux of matter and energy. Yet its ecology remains poorly understood.

At the ALOHA oceanographic station, sixty miles north of the island of Oahu, in Hawai'i, microbial oceanographers Edward F. DeLong of the Massachusetts Institute of Technology in Cambridge and David M. Karl of the University of Hawai'i in Honolulu, and several colleagues sampled microorganisms at depths ranging from 32 to 13,000 feet. Their plan was to analyze how the gene sequences varied by depth, taking into account the physical, chemical, and other biological properties of the water column, as measured by ALOHA.

Sure enough, DeLong and his colleagues detected predictable trends in gene function associated with the distinct microbial communities they found living at various depths. Genes involved in metabolism from sunny surface waters, for instance, often code for photosynthetic pathways, whereas in deep waters, genes for metabolizing methane and other sources of chemical energy predominate. From shallow waters, the investigators also recovered a surprising number of virus genomes that had incorporated genes involved in photosynthesis from their cyanobacteria hosts. In the genetic bazaar of the sea, such gene exchange among microorganisms may be quite widespread. (*Science* **311**:496–503, 2006) —*Graciela Flores*


BRING THE LARVAE.
EXPLORE A WORLD OF INSECTS WITH YOUR KIDS AT THE NATURAL HISTORY MUSEUM!
20TH ANNUAL bugfair
See amazing live bugs and spiders, watch an insect chef cook up some creepy bug cuisine, and shop for books, supplies, artwork, and toys from more than 60 vendors. The Bug Fair is FREE with paid admission to the Natural History Museum of Los Angeles County.
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SAMPLINGS

Survival of the Rarest

Tropical forest, Barro Colorado Island, Panama

Tropical forests may be more resilient than their reputations would have you believe. The forests appear to bolster the tree species most vulnerable to extinction: the rare ones.

Christopher Wills, an evolutionary biologist at the University of California, San Diego, led a study in which international teams took tree censuses on plots in seven tropical forests around the globe. The team repeated the censuses after five years for some plots, after ten years for others. Locally common species, it turned out, make up most of the young trees in a given age class, but locally rare species have lower death rates. The net result is that rare trees become more common within their age class as time passes.

Why might rare species survive preferentially? Some avoid competing for the same resources that more common species require. Others escape pathogens and predators that target their ubiquitous neighbors. Evidence that nature favors diversity suggests that tropical forests may be able to recover fully and quickly from at least moderate destruction. That's good news, but Wills isn't celebrating. "If the forests are slashed and burned," he warns, "all bets are off." (*Science* **311**:527–31, 2006)

—*Samantha Harvey*

Sing It to Me

Juvenile (left) and adult male zebra finches

Young male zebra finches learn to sing by listening to adult tutors—often their fathers—and by rehearsing endlessly. To get a tune just right, a young bird must compare the sounds it makes with its memories of the songs its tutor sang. The memories—or "sound templates" for birdsong—must be stored somewhere in the bird's brain, but where? Until now, investigators have primarily searched parts of the brain responsible for singing and song learning. Now, Mimi L. Phan and David S. Vicario, both neuroscientists at Rutgers University in New Brunswick, New Jersey, and a colleague have found evidence of a template elsewhere: in a part of the brain generally known as the NCM, which plays a role in hearing.

Phan and Vicario played a tutor's song to young zebra finches for several weeks, then switched it off for a month while the birds matured. The neuroscientists then played a selection of tunes that included the tutor's song, the birds' own songs, and new songs, while recording the electrical responses of neurons in the birds' NCMs. By applying a standard test of familiarity, the investigators determined that the neurons in the NCM recognized the tutor's song. What's more, the birds that were most familiar with the tutor's song reproduced it most accurately. (*PNAS* **103**:1088–93, 2006) —*G.F.*

Fish Story in Reverse

*Smallest fish, a male anglerfish (*Photocorynus spiniceps*, shown above left at actual size), is fused to the back of a much larger female.*

In January, ichthyologists announced they'd discovered the world's smallest vertebrate. One female *Paedocypris progenetica*, a carp relative from Indonesian swamps, measured just 7.9 millimeters. That's not so small, countered Theodore Pietsch, an ichthyologist at the University of Washington in Seattle. In September he'd described *Photocorynus spiniceps*, a deep-sea-dwelling anglerfish from the Philippines, with males as small as 6.2 millimeters. Males bite into females and fuse for life. They supply sperm; females supply eggs, food, locomotion, and everything else. (*Proceedings of the Royal Society* B, forthcoming; *Ichthyological Research* **52**:207–36, 2005) —*R.K.*

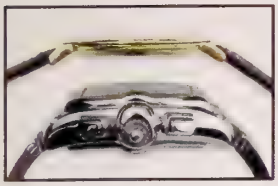
Impermafrost

People living in the Far North have often built their homes on solidly frozen earth. But their heirs may have to contend with wildly listing floors. Permafrost—soil frozen for two or more years, with a thin top layer that may seasonally thaw—makes up about a quarter of the land area in the Northern Hemisphere, roughly 4.1 million square miles. As the Earth warms, however, permafrost is proving to be anything but permanent.

That's what David M. Lawrence of the National Center for Atmospheric Research, and Andrew G. Slater of the University of Colorado, both climate scientists based in Boulder, have found. They ran a powerful computer model to predict the distribution of the top eleven feet of permafrost under various scenarios of greenhouse-gas emissions. The model predicted that if emissions remain high, as much as 90 percent of the North's surface permafrost will thaw by 2100. One consequence is that northern soils may slowly dry out, contributing somewhat—as may increased precipitation—to a 28 percent rise in freshwater runoff into the Atlantic Ocean.

Perhaps even worse, thawed soils could release methane and carbon dioxide into the air, intensifying the greenhouse effect. Whether enough trees will grow on the newly defrosted terrain to mop up the excess carbon dioxide remains to be seen. (*Geophysical Research Letters* **32**:L24401, 2005) —*S.R.*

The Swiss Breakthrough!! The Thinnest Calendar Watch Ever Made



The Steinhausen engineers set out to make the thinnest, lightest, most beautiful watch in history. After five grueling years of constant research, development and testing, they introduced the Dunn Horitzon Rasierer. Dunn Horitzon is German for "Thin Horizon." "Rasierer" refers to being razor-thin. At less than two millimeters thick, you can't buy a slimmer model that includes a two-digit calendar. The Europeans lauded it for its sophistication and aesthetic look and design – it was one of the top attractions at the Basel Convention for watches and clocks in Switzerland (the most important annual clock and watch show worldwide for the past 34 years). Italian art schools are using the Dunn Horitzon as an example of the perfect design model. The Japanese praise the Dunn Horitzon for its quality and sophisticated design. And the American consumer paid the ultimate compliment by making it one of our top-selling timepieces.

Unique Design and Engineering

The Dunn Horitzon Rasierer is made from stainless steel but has been designed with a special German-engineered alloy that removes almost all the weight, making it so thin that you won't even notice it's strapped to your wrist. And if you have sensitive skin, don't worry. Our gold watch is plated with 24 karats and five microns of gold that will never lose its shine or fade away.

Satisfaction Guaranteed

Your appreciation of the Dunn Horitzon Rasierer is certain to increase over time. We are so confident that you will receive such an abundance of compliments, that as part of our celebration of this glorious introduction, we will include a free Steinhausen patented money clip, a $40 value, with each order. If you are dissatisfied for any reason with the Dunn Horitzon Rasierer, return it and pay only shipping and handling but keep the money clip as our gift.

Accept No Imitations

Steinhausens are considered must-have works of art among Japanese and European collectors. Steinhausens are only found in the finest retailers and through Steinhausenonline.com. Be the first to wear this remarkable new addition to the world-famous Steinhausen line.

Solid. Hefty. Handsome.
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When the Moon Hits Your Eye

More knowledge and better data only deepen the beguiling appeal of the best-known object in the night sky.

By Neil deGrasse Tyson

Countless cultures have spun countless tales about Earth's nearest neighbor in space. To the ancient Greeks, the Moon was a pale-faced young woman riding across the sky in a horse-drawn chariot. To the Aztecs, no strangers to blood and gore, the Moon was the severed head of a malicious daughter of the Earth goddess, which her brother, the Sun god, had flung into the sky.

But colorful tales don't satisfy scientists. We want data. So as soon as word of the newly invented telescope spread across Europe, astronomers began to acquire or construct their own versions of this marvel and turn them toward the Moon. Early in August of 1609—a couple of months before Galileo built his first telescope—the English mathematician and astronomer Thomas Harriot made the first known drawing of the lunar surface as seen through the lens of an optical instrument. Half a year later, a month before Galileo's first batch of telescopic observations appeared in print, Harriot's friend Sir William Lower, an English country gentleman, wrote up his own observations of the Moon in a letter to Harriot:

> In the full she appears like a tarte that my cooke made me last weeke; here a vaine of bright stuffe, and there of darke, and so confusedlie all over. I must confesse I can see none of this without my cylinder.

That's what happens when you look at the sky while you're hungry.

No surprise that the Moon was one of the first celestial objects to be telescopically described and tracked: It's big. It's close. It's bright. No surprise either that, nearly four centuries later, the Moon became the first destination of the U.S.–Soviet space race. As President John F. Kennedy had hoped, Americans—specifically the *Apollo 11* astronauts Neil Armstrong and Buzz Aldrin—became the first people to set foot on the Moon, on July 20, 1969. A full decade earlier (not that Americans think about it much), the Soviet Union

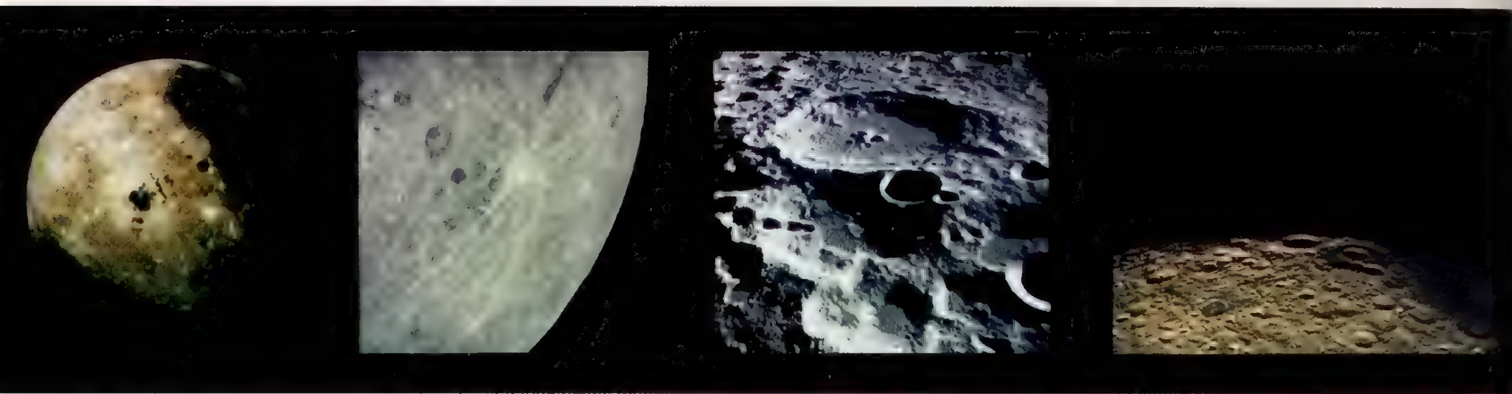
David De Lossy, Full moon rising

had become the first nation to land a spacecraft on the Moon and the first to photograph the Moon's far side—which is why many surface features on the far side have names like Mare Moscoviense and Gagarin crater. The Soviets were also the first to put a vehicle on the Moon: an eight-wheeled robotic rover. But flesh-and-blood Americans, walking on the lunar surface and planting the flag, were what U.S. presidents wanted the world to see.

You might think space scientists would have answered all the big questions about the Moon by now, having studied it more than any object in the universe besides Earth itself. You might even think no country would want to bother sending its citizens there anymore. Wrong on both counts. Some of the Moon's deep polar craters might harbor ice, which can be turned into drinking water and rocket fuel. Some of the rocks ejected from Earth during early catastrophic meteorite impacts may have been scattered across the Moon's unweathered surface. Some of those rocks—whose Earth-based cousins would long ago have been destroyed by our planet's active geology—might harbor intact fossil evidence of Earth's earliest life-forms. Some of the Moon's mineral resources could conceivably be extracted and used by short-term and long-term lunar missions. And as you read this page, not only America's National Aeronautics and Space Administration, but also the European Space Agency, the China National Space Administration, and the Indian Space Research Organisation are all actively planning their next missions to the Moon.

Truth can be even weirder than fiction. Today, astrophysicists and geologists generally agree that the Moon formed several billion years ago when a Mars-size protoplanet slammed into the adolescent Earth [*see "Moonstruck," by G. Jeffrey Taylor, September 2003*]. The impact must have been something to behold. It kicked up about a hundred quintillion (10^{20}) tons of rock vapor and molten rock blobs—bits and pieces of Earth mixed with bits and pieces of the impactor—some of which shot tens of thousands of miles into space.

Most of the material that hurtled outward eventually fell back to Earth. Some of it got no farther than about 12,000 miles from our planet's center, and formed short-lived rings. Of the material that traveled farther, most of it formed more durable rings, akin to the gorgeous ring system that now encircles Saturn. From that disk-shaped orbiting platform, the bits and pieces of rock began to coalesce, first through chemical adhesion and ultimately through mutual gravitational attraction. Within just a few decades the bulk of the rubble had merged into a single giant sphere, orbiting twenty times closer to Earth than the Moon does today. It must have been a spectacular sight—though no one was around to see it—to have the Moon looming



twenty times larger in the sky than it does today. The image gives fresh meaning to a perennial question, "Why does the full Moon look so large on the horizon?"

In case you're wondering about that 12,000-mile boundary, it's known as the Roche limit. Inside that limit, Earth's tidal force exceeds an object's ability to hold itself together solely through the strength of its own gravity. So if you were a pile of rubble—rather than a living organism, held together by molecular bonds—and you had the bad luck to wander into that zone, you would swiftly disassemble into your component rocks.

To most people, tides are just the daily back-and-forth sloshing that takes place where the ocean meets the shore. But that's just the most visible sign of what happens when one side of a rotating cosmic object finds itself closer than the other side to a strong source of gravity. As the object rotates, gravity pulls more powerfully on the side facing that source than it pulls on the far side, raising tides even in solid matter. "Solid body" tides stretch and pull solid matter, rhythmically deforming the object and thus causing friction deep within.

The deformations show up in the object as bulges, which would normally align with the offending source of gravity. But because the newborn Moon rotated quickly, its tidal bulge ended up a bit ahead of, rather than aimed right at, Earth. Meanwhile, the Moon was having a simultaneous and similar effect on Earth. When you do the math, you find that all that friction and bulge-making slowed Earth's rotation, slowed the Moon's rotation, and slung the Moon into ever-higher orbits. And as the orbits grew progressively larger, the strength of the tidal forces precipitously dropped.

Since its youth, then, the Moon has been rotating so slowly that it takes exactly the same amount of time to complete one full rotation as it does to execute one full orbit of Earth. In fact, Earth has locked the Moon into that arrangement—a natural culmination of their tidal pas de deux—just as Jupiter has locked its inner satellites and Pluto has locked Charon, its largest moon. Whenever two bodies reach this stage, you get a "far side" dilemma: observers on one object (say, Earth) never get to see more than one side of the object that orbits them (the Moon).

The Moon's tidal forces on our planet continue to slow Earth's rotation. Every century, the length of our day increases by about one and a half milliseconds. (To keep up, earthlings invented leap seconds, but that's another story for another afternoon.) Meanwhile, the Moon's orbit is continuing to grow, by about one and a half inches per year, and so the lunar month is getting longer. What's going on is that the Moon is trying to get even and give Earth its own far side. That will happen when Earth's rotation rate has slowed enough to be equal to the Moon's orbital period. The Earth-Moon system will then have achieved a "double tidal lock." This never-invented wresting hold may sound rare, but it's actually common, particularly among double-star systems in our galaxy. Right here in our own backyard, Charon has managed to lock Pluto just as Pluto has locked Charon.

By the time the Moon tidally locks Earth, the system will have slowed down so much that the Earth day and the lunar month will both last almost fifty present Earth days, greatly simplifying the calendar. Long before that, though, the Sun will become a red giant and vaporize the Earth-Moon system. But let's ignore that complication.

Consider instead the Sun's tidal influence on the Earth-Moon duo. The Sun, too, is busy doing the tidal lock—perpetually slowing Earth's rotation so that, if there were no Moon, our planet would eventually show the Sun only one face. Meanwhile, the Moon will reverse its earlier trend and begin to spiral back toward Earth. Eventually the Moon will drift within the Roche limit, break apart, and end up, once again, briefly resembling the rings of Saturn.

The ever-changing lunar orbit is, by happy coincidence, just the right size to give sky watchers a thrill. The Sun is roughly 400 times larger than the Moon, but for the moment, it's also about 400 times farther away. To an observer on Earth, then, they both appear about the same size on the sky. So dumb luck makes for striking

total solar eclipses, in which the Moon just manages to cover the Sun's bright disk, turning day into night and yielding a rare view of the dim but majestic solar corona.

Before you start thinking that Earth's sky was preordained to look beautiful only for people, consider that *T. rex* and friends, too, saw beautiful eclipses. So will our successors in the tree of life hundreds of millions of years from now. Only after a billion or so years will the Moon have drifted far enough away to look smaller than the Sun at all times, thus ending a glorious era of eclipse watching.

We can all thank the space race, by the way, for evidence that the distance between Earth and the Moon is changing. In 1969 astronauts Neil and Buzz placed the first array of "corner reflectors" on the lunar surface. The array, which looks a little like an open waffle iron, is made up of a hundred small quartz cubes cut in half at a forty-five-degree angle and secured to an aluminum panel. Any beam of light that hits that configuration, regardless of the incoming angle, gets triply reflected within the half-cube and returns whence it came, exactly parallel to the original beam. Nothing magical here, just the ordinary rules of geometry. Hurl a bouncy ball into the corner of a room, and the same thing happens; apart from the curving effect of gravity, the return path of the ball is parallel to its original path.

Now aim a laser from Earth to the Moon's corner reflector, and the beam bounces right back to you. Time the round trip, multiply that by the precisely known speed of light, and, behold, you've got the precise distance from Earth to the Moon.

Within a few years after the first reflector was laid down, three more followed—two courtesy of the United States and one, the Soviet Union. More than three decades' worth of measurements have now shown that the Moon is moving away from Earth at the aforementioned rate of one and a half inches a year. Clearly, tidal forces are still busy working.

No matter the details of its orbital plight, the Moon remains an alluring object in both the daytime and the nighttime skies. At dusk or dawn when the crescent Moon gleams, you can often see the rest of the lunar orb as a kind of ghost, even though no sunlight is hitting it directly. That phenomenon is officially called earthshine (though I have always preferred "moonshine"), and Leonardo da Vinci, early in the sixteenth century, was the first to figure out its cause. Unlike his contemporaries, who thought the Moon was endowed with its own luminosity, Leonardo understood that earthshine is evidence that the Moon reflects the light of Earth.

Indeed, earthlight is far brighter than moonlight. Averaged over both light and dark areas, the barren lunar surface reflects only 12 percent of the

light that reaches it. By comparison, primarily because of all the white clouds in Earth's atmosphere, but also because our vast oceans reflect a good deal of light, a patch of our planet's surface material is, on average, three times more reflective than an average patch of the Moon. And because Earth is more than three and a half times wider than the Moon, it has thirteen times more surface area to do the reflecting. So, full Earth as seen from the Moon is forty times brighter than the full Moon as seen from Earth. You could easily read by earthlight. Full Earth reflects a lot of light back out into space. And when that light reaches the Moon, enough is reflected from the otherwise unlit portion of the near side to make the dark surface faintly visible to the naked eye on Earth.

So yes, earthshine is real. So is moonshine, as we all knew already. But earthrise is not. From the near side of the Moon, tidally locked and forever facing Earth, our planet simply hovers in the sky, where it neither rises nor sets. The famous "Earthrise" photograph, taken in 1968 by *Apollo 8* astronauts, was snapped as they orbited the Moon. But when you're in orbit, the whole sky continually rises and sets for you. For a permanent resident of the Moon's far side, though, Earth sits forever out of sight. Visitors who want to pitch a tent there yet still talk to their pals on Earth will need to set up relay stations just past the outer limits of the far side. From there, Earth is low on the horizon but fully visible—and ready for you to phone home.

The design of NASA's newest robotic mission to the Moon, called the Lunar Reconnaissance Orbiter, just passed muster, and the craft is now scheduled for launch in 2008. Within a decade, Chinese and Indian robots may be traversing the Moon. Within a few more decades, ordinary citizens of planet Earth may be doing so as well. The early trips, which will launch from Earth with just enough speed to coast to the Moon, will take about three days; with continuous-thrust engines, there's no telling how quick the later ones could be.

Although earthlings certainly love the place, the Moon is not the sole satellite of our affections, and we intend to send spacecraft to orbit, study, and occasionally land on some of the solar system's other moons as well. Some of those objects, a few of which might harbor life, have had vehicular visitors already. Between 1995 and 2002 *Galileo* flew close to five of the threescore moons of Jupiter—including icy Europa, which it circled at such close range that features as small as a school bus (though no actual school buses) showed up on camera. Since 2004 *Cassini* has been scrutinizing many of the nearly fifty moons of Saturn. On Titan, Saturn's largest moon, rivers of liquid methane have carved channels in the frozen surface; on Enceladus, a smaller Saturnian moon, jets are streaming out of the south polar region, unequivocally signaling geologic activity. Pluto and its satellite Charon are yet another destination: in 2015 NASA's *New Horizons* spacecraft, which left Cape Canaveral on January 19, 2006, should reach them.

To adults of "a certain age," it was not long ago that the moons of the solar system were simply points of light: you tallied them and then ignored them, in favor of the planets they orbited. But the twin multiplanet Voyager missions of the 1970s and 1980s showed that no two moons of the solar system are the same. Each has its own geology, impact history, temperature profile, and orbital dynamics. In the minds of scientists and citizens alike, the moons became worlds unto themselves. And just like Earth's moon, they became destinations worthy of our dreams and, of course, our missions.

Astrophysicist NEIL DEGRASSE TYSON *is the director of the Hayden Planetarium at the American Museum of Natural History. His* Natural History *essay "In the Beginning" (September 2003) won the 2005 Science Writing Award from the American Institute of Physics. An anthology of his* Natural History *essays will be published this year by W.W. Norton.*

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BIOMECHANICS

Secrets of the Sacred Lotus

For the lotus leaf, being dirt-free means shunning water with a rough, waxy surface.

By Adam Summers ~ Illustrations by Tom Moore

According to my wife, I can't see dirt. I'm oblivious to disorder, she says, blind to dust, ignorant about the positive effects of a good vacuum cleaner. Truth be told, more pressing things always *do* seem to suck up my time. But in my usual excuse—the endless quest to keep up with the latest research—I may have found the perfect rejoinder to further spousal recrimination. Recently released in the United States, it's a wonderfully clever product that mimics the leaf surface of the lotus plant. And it has the potential to make another endless quest—the quest for a clean house—a thing of the past.

The sacred lotus *(Nelumbo nucifera)* has long been a symbol of purity in Asian cultures, and for good reason. Lotus roots are embedded in muck and get many of their nutrients from the soil, yet the plants seldom have much noticeable grime on their surfaces. In fact, if you think about it, wouldn't you say most plants stay pretty clean? No doubt that's a good thing, because a dark smear of dirt would surely interfere with photosynthesis. There's no paucity of dirt, of course, so it makes sense to suppose that the cleanliness of plant leaves is related to the ease with which water washes away any offending particles of dirt.

In the early 1970s Wilhelm Barthlott, a botanist now at the University of Bonn in Germany, noted the dirt-resistant properties of the sacred lotus leaf. He and his colleagues have spent the intervening three decades cataloging the fine structure of leaf surfaces. Along the way, they've tried

commercializing their research, in hopes of helping the rest of the world shed grime as readily as plants do.

What Barthlott and company discovered is a bit counterintuitive. The secret to the self-cleaning properties of a leaf is its extreme ability to shed, not dirt, but water. Such surfaces are described as superhydrophobic; they are so water repellent that H_2O just about leaps off them, taking dirt with it.

A hydrophobic surface, such as a piece of waxed paper, refuses to be wetted by water. On such a surface, water molecules have a greater affinity for other water molecules than they do for the wax.

Wettability can be quantified by placing a drop of water on a surface and measuring the angle between the edge of the drop and the substrate. Try it: Squeeze a drop onto a clean glass surface, and it will spread out nearly flat, with a contact angle of less than twenty degrees. On waxed paper, though, the same-size drop will stand up high and proud, with a contact angle of ninety degrees or more. In theory, on a surface it just couldn't bear to touch, a water droplet would make so little contact that its angle with the surface would be just shy of 180 degrees. Lotus leaves actually approach such sublime levels of water hatred with contact angles of about 140 degrees.

When a drop of water falls on your skin, clothes, or any other surface, it flattens out from the impact, jostling and lifting dirt as it splats. On a wettable surface the drop stays flat, and the dirt simply settles back onto the surface. In contrast, when a drop hits an unwettable surface, the cohesive forces between the water molecules in the drop are much greater than the forces between the water molecules and the surface. So, almost immediately after the drop flattens from the impact, it rebounds into a more nearly spherical shape. Any dirt touching the drop as it flattens becomes suspended in the drop or attached to it as it rebounds; either way, the dirt doesn't settle back on the surface. Best of all, since the droplet is round, it readily rolls down any slight incline, carrying the dirt away.

The connection between hydrophobicity and cleanliness is old news—it's why people wax their cars. No matter what the ads would have you believe, wax is not scuff resistant; instead, wax makes it harder for dirt to stick and easier to wash dirt away.

But the secret of the superhydrophobic lotus leaf is more than just a smooth coating of wax. With a scanning electron microscope, Barthlott and his colleagues discovered that lotus leaves (and the leaves of many other plants) are not smooth at all. Rather, their surfaces are covered with microscopic bumps and ridges, arranged in a complex pattern. The bumps, each just ten microns or so across, keep a water droplet up and moving along the contoured surface.

When a drop falls on such a surface, it deforms as it fills in the gullies. But the cohesive forces between the water molecules quickly haul the drop out of the microvalleys, along with any resident dirt. Once the drop rebounds, it touches only the peaks of the little wax mountains, leaving such a tiny area in contact with the surface that the adhesive forces between the drop and the leaf's contours are vanishingly small. Without these downward pulls, the cohesive forces between the droplet's water molecules are able to hold the droplet in a nearly spherical shape as it rolls off the leaf [*see illustrations below*].

Water droplet hits the surface of a lotus leaf and dislodges resident dirt particles (above left). The droplet then rebounds into a nearly spherical form, because it "hates" to make contact with the waxy, bumpy surface of the leaf (above right). The dirt has no strong affinity for the leaf, either, and sticks with the droplet, which can roll down the slightest incline, picking up more dirt as it goes.

Barthlott patented the pattern of bumps on the hydrophobic surface and dubbed it "the Lotus effect." A German paint company then licensed the patent and developed a paint with emulsified waxes that dries into a microscopically rough surface. Introduced in Europe in 1999, the paint arrived in North America this past fall. A house painted with Lotus-effect paint can stay clean as long as the surface is regularly washed with water. No scrubbing allowed, though: that would disturb the microscopic pattern of the surface and thus weaken the self-cleaning properties of the paint.

At this writing, the product is suitable for exterior use only, because of the need for regular dousings. So until my office interior can be hosed off, I may have to take refuge in the idea that the rougher you are around the edges, the cleaner you are likely to be.

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NATURAL HISTORY
APRIL 2006

The Biggest Fish

Unraveling the mysteries of the whale shark

By Steven G. Wilson

One hot, windless May morning, five of my colleagues and I boarded our small research boat and motored out into the waters of Western Australia's Ningaloo Reef. We were searching for whale sharks—the world's largest fish—hoping to attach electronic tags to several animals to study their migration patterns and diving behavior. Waiting for our spotter plane to locate a shark, we passed the morning in casual conversation.

Finally the radio crackled to life. "I've got two sharks, about a mile off Tantabiddi Passage!" The vessel suddenly transformed as everyone scrambled to gather and don masks and fins. As we skimmed over the water, I struggled to attach a dart and tag to my Hawaiian-sling polespear—a sport-fishing spear powered by a thick rubber band. Five minutes later, two large, dark shadows were looming beneath the ocean's surface, about a hundred feet off the bow.

I plunged in, but once in the water I had to ask the boat crew for directions to the unseen giants. I swam toward where they signaled. A cobia came into view, a game fish that often accompanies whale sharks, and I knew I was close. Then, slowly, the outline of a gaping oval mouth and, behind it, an upright tail fin resolved from the featureless blue background. As I swam closer, the shark's tapered body and distinctive checkerboard markings also came into focus.

My attention, though, was drawn to the first of its two dorsal fins. The base of the fin was the target for the dart and tag. My colleagues in the water measured the animal (fifteen feet long) and determined its sex (female), while I positioned myself along its side. When they were finished, I cocked the polespear and released it. The dart penetrated the whale shark's tough hide, but not as deeply as I had hoped. Unless adjust-

Twenty-five-foot whale shark swims just below the surface at Ningaloo Reef, off Australia's west coast.

ed, it would pull out in a matter of days. With a quick shove of the polespear, I pushed the dart deeper. The shark reacted with a flick of its tail, then dove.

I watched with satisfaction as the tagged shark sank slowly into the depths. I felt a jolt to my lower back, and suddenly found myself being propelled through the water. All I could see was a whirl of spots. It took me a moment to comprehend that another, much larger whale shark had struck me with its dorsal fin and was pushing me forward. With all the excitement, I had completely forgotten about the second shark! Stunned but unhurt, I dislodged myself and swam back to the boat to reload my polespear. By the time I returned, the second whale shark was about twenty-five feet beneath the sea surface. I filled my lungs with air, then dove after the thirty-five-foot leviathan. This time the dart penetrated with ease, and the shark showed no reaction. My job completed, I swam back to the vessel and learned that the plane had located more sharks. In spite of my little fright, there would be no time to dwell on it that day. Whale sharks were popping up everywhere.

Fortunately, accidental clobbering is the only danger whale sharks *(Rhincodon typus)* present to people. Unlike their toothier, more aggressive relatives, whale sharks have such gentle dispositions that the chance to swim with them has spawned lucrative ecotourism industries in several places where they gather. Ningaloo Reef, the Philippines, Belize, and the Baja Peninsula of Mexico have all benefited from whale shark tourism. But the same lumbering slowness and tendency to swim near the surface that make whale sharks a favorite with snorkelers also make them easy targets for fishermen, and frequent victims of collisions with ships. Before the mid-1980s, only a few

hundred whale shark sightings had been reported worldwide; in the past two decades, human interaction with them has grown substantially.

Yet despite the increasingly frequent contact between people and whale sharks, and despite their presence throughout the world's tropical and temperate seas, including the waters of some 125 nations, surprisingly little is known about them. Marine biologists don't know much, for instance, about how whale sharks reproduce: no one has ever observed their courtship, mating, or birth. How they interact socially is anyone's guess. What they do on the prolonged, deep dives they make is yet another mystery. No one knows how many there are, or whether their populations are rising, stable, or declining. Given their largely unregulated harvest and vulnerability to capture, however, decline seems most likely.

Whale shark feeds passively on small prey by swimming with its mouth open. A snorkeler watches from above.

To a small troop of biologists—myself included—those gaps in knowledge present a challenge. Our recent research into the whale shark's feeding habits, diving behavior, and migrations is slowly giving us a better understanding of its role in the marine environment. Our hope is that we will be able to use this knowledge to help ensure the species' survival, before it becomes another casualty of the changing world.

At least some facts about whale sharks are clear. First, the name "whale shark" is somewhat misleading: the animals are indeed sharks, but they are "whales" only by virtue of their size. They grow more than forty feet long (the length of a luxury motor home), and there are unsubstantiated reports of a sixty-five-footer that weighed thirty-seven tons. Unlike most sharks, though, whale sharks are filter feeders. They share that behavior, fittingly, with the world's biggest animal, the blue whale. Whale sharks suck dense concentrations of minute prey, such as krill and other zooplankton, fish spawn, and small fishes, into their enormous mouths. To collect the prey, they filter out the accompanying water through sievelike gill plates, and then expel it through their gill slits.

Whale sharks often feed passively by swimming slowly with their mouths agape. They can also assume a head-up, tail-down feeding posture, sometimes bobbing up and down near the surface to pump prey-filled water over their gills [*see illustration on opposite page*]. Oddly, they are not closely related to the other two filter-feeding sharks, the basking shark and the megamouth shark. Instead, their closest relative is the nurse shark, a bottom-dwelling predator. In spite of their filter-feeding ways, whale sharks possess some 27,000 minute teeth, similar to teeth in the fossil record that date to about 55 million years ago. Little else is known of their evolutionary history.

Scientific knowledge of whale shark reproduction is based on a single female, harpooned off Taiwan in 1995, that carried 301 embryos in various stages of development. Biologists know from that catch that the pups are born alive when they are about two feet long. (The eggs hatch inside the mother.) Studies of growth rings in vertebrae suggest that whale sharks reach sexual maturity when they are between twenty and thirty years old, and may live for several decades more. Young whale sharks less than ten feet long are rarely seen, leading some investigators to speculate that they occupy deep, offshore habitats during that most vulnerable stage in their lives. Newborns have been recovered from the stomachs of a blue shark and a blue marlin. The adults likely have few natural predators, except perhaps great white sharks and killer whales.

The whale shark's most prominent feature—other than its sheer magnitude—is its distinctive markings. Pale spots speckle a grid of bars and stripes atop the shark's blue, gray, or brownish back and flanks (its belly is white). The markings prob-

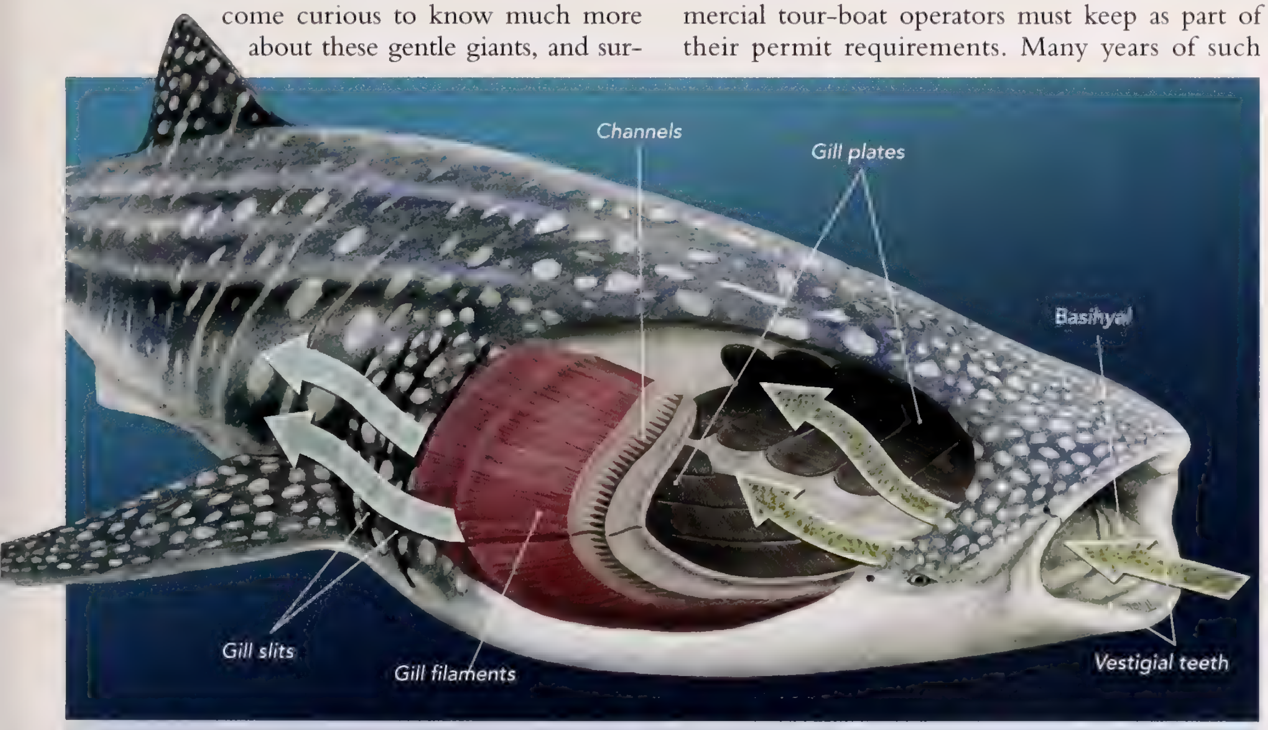
ably act as camouflage, mimicking wave-dappled sunlight in the water or perhaps a school of small fish. If so, an important function of the markings may be to conceal juvenile sharks from predators.

Individual sharks have unique markings. Recently a team led by Bradley M. Norman, a marine biologist with the marine conservation group Ecocean in Perth, Western Australia, adapted a computer algorithm, originally devised for mapping stars, to identify individual whale sharks from photographs of their spots. The group is building a database of identifiable whale shark photographs (available at www.whaleshark.org), which should help biologists track the animals and learn more about their travels and behavior.

Ningaloo Reef lies along a lonely 160-mile stretch of outback coast and is Western Australia's answer to the Great Barrier Reef. Although smaller and less well known than its east-coast counterpart, Ningaloo is famed for the large marine animals—humpback whales, manta rays, whale sharks, and others—that gather seasonally in its waters. I first visited the reef in 1997 and spent nearly every day of my two-week stay snorkeling with whale sharks and photographing them. By the time I left, I'd become curious to know much more about these gentle giants, and surprised by how little science could tell me. Nine months later, I enrolled in a Ph.D. program at the University of Western Australia in Perth to study the species at Ningaloo. I wanted to know why the whale sharks gather on the reef each year, and why more sharks come in some years than they do in others.

Whale sharks, like many other shark species, segregate themselves by sex. At Ningaloo Reef most whale sharks are immature males, suggesting that they come to feed, not to mate. The region's oceanography may explain why they—and perhaps some of the other large creatures—visit the reef. Flowing southward along the continental shelf, the Leeuwin Current dominates the area. But a smaller countercurrent called the Ningaloo Current flows northward between the Leeuwin Current and the reef. Each fall, the two currents join to form a gyre, which may keep nutrients and prey in the area rather than flush them out. It hardly seems coincidental that that's when the whale sharks arrive on the reef.

Still, whale shark abundance varies widely from year to year. Some years, as many as a few hundred sharks come to Ningaloo Reef; in other years, the numbers are much lower. To determine why, I began by looking at patterns in whale shark abundance derived from records of shark interactions that commercial tour-boat operators must keep as part of their permit requirements. Many years of such



Whale shark is a "suction filter-feeder" on dense congregations of minute prey such as krill. It strains mouthfuls of food-filled seawater (brownish-blue arrows) through porous gill plates and consumes the prey that remains in its mouth. Channels behind its gill plates direct the filtered water over its gill filaments, which extract oxygen for respiration. The filtered water (blue arrows) is then released through the whale shark's gill slits. The animal can generate suction to draw in its meals, perhaps by expanding its oral cavity and depressing its basihyal, a tonguelike structure on the floor of its mouth.

data show that fewer sharks are present in El Niño years than during La Niña years.

In La Niña years, ocean temperatures and sea levels in the western tropical Pacific are relatively high; during El Niño episodes, water temperatures and sea levels are lower. Both patterns have long-range effects on climate and currents from Australia to South America, as well as in many other parts of the world. I began to suspect that the El Niño phenomenon somehow negatively affects the whale sharks' food supply at Ningaloo Reef.

Signs of overfishing have begun to appear: catches have declined, and fish have gotten smaller.

To confirm my suspicions, I first had to determine what the whale sharks eat along the reef. They were already known to feed on schools of a tropical species of krill, *Pseudeuphausia latifrons,* but no one could say whether it is their primary food. To answer that question, I examined fecal samples from whale sharks, which divers had collected at the reef over several years. All the samples included crustacean remains that resembled krill, and a genetic analysis later confirmed that the species was indeed *P. latifrons.* Surveys using sonar to look for krill while whale sharks were congregating on the reef also turned up plenty of krill, forming schools about the size of a football field and some ninety feet deep. Most tellingly, when my colleagues and I came across schools of krill, we almost always found whale sharks feeding on them.

Do krill populations fluctuate with El Niño, too? As part of a study on fish larvae, biologists from the Australian Institute of Marine Science in Townsville set traps each month for two consecutive summers. I was able to study the krill and other zooplankton they caught. As luck would have it, the first year had strong El Niño conditions and the following year strong La Niña conditions. In line with my hypothesis, krill abundance proved to be much higher during the La Niña year. Two years of data is not proof, but it does offer a good lead.

How does El Niño influence the production of krill? The Leeuwin Current that dominates the reef is stronger in La Niña years than it is in El Niño years. Paradoxically, however, the stronger current suppresses nutrient upwelling, and that leads to lower chlorophyll concentrations and a diminished supply of most kinds of zooplankton in La Niña years. So what accounts for the high krill abundance we discovered in a La Niña year? For now, at least, that remains a mystery.

Although I finished my doctoral studies in 2001, I still return to Ningaloo Reef each whale shark season. In 2002 I collected tissue samples for a genetics study by a graduate student at the University of South Florida in Tampa, comparing DNA from whale sharks in the Atlantic, Indian, and Pacific oceans. Once finished, the study will show how much genetic mixing takes place between whale sharks in the three ocean basins. That should shed some light on how much impact regional fisheries may have on the global abundance of whale sharks, and thus guide efforts to manage and conserve them.

My surprise encounter with the dorsal fin of a whale shark resulted from an effort to answer another basic question: Where do the Ningaloo Reef whale sharks go in the winter, spring, and summer? In 2003 and 2004, I joined three fellow marine biologists—Brent S. Stewart of Hubbs–SeaWorld Research Institute in San Diego, Jeff J. Polovina of the U.S. National Marine Fisheries Service in Honolulu, and Mark G. Meekan of the Australian Institute of Marine Science in Darwin—in attaching pop-up archival tags to nineteen sharks. The tags record data about the light level, depth, and temperature of the tagged fish's environment until a preprogrammed date. Then the tags detach, float to the surface, and transmit their archived information to satellites. From those data, the sharks' movements can be reconstructed to within about a hundred miles.

We recovered several months' worth of data from each of six tags. All six sharks had moved northeast after leaving Ningaloo Reef, and several individuals had approached the Indonesian coast, where, we feared, they risked becoming fishermen's quarry. Our depth and temperature data also showed that whale sharks inhabit a more extensive niche than anyone had suspected. The animals spent most of their time in surface waters, but they also dove occasionally to depths of more than 3,200 feet, where temperatures drop as low as forty degrees Fahrenheit—a big change from the balmy eighty-four-degree waters at the surface. Why do they dive? Perhaps the sharks need to cool off, or perhaps they are feeding on some unknown, deepwater prey.

Since they spend so much time near the surface, though, we realized we might track them much more precisely with a different kind of tag: a satellite-linked radio transmitter. With such a transmitter, an animal's position can be determined to within a mile anytime the transmitter's antenna is above the sea surface. In 2005, with the help of John D.

Stevens, a shark biologist, and Matthew G. Horsham, a mechanical engineer, both at Australia's Commonwealth Scientific and Industrial Research Organisation in Hobart, we attached these instruments to several whale sharks at Ningaloo Reef. Some tagged sharks moved northeast toward Indonesia, and some moved northwest.

Tags of various kinds have been attached to whale sharks in the waters of several other countries as well, including Belize, Honduras, Japan, Mexico, the Seychelles, and Taiwan. Most of those tagging studies are not yet published, but preliminary data suggest that whale sharks migrate long distances. One shark traveled from Mexico's Sea of Cortez across the Pacific, a distance of more than 8,000 miles.

Whale sharks have long been hunted at many of their seasonal gathering sites, typically by artisanal fishermen using harpoons. In some places the catches have been quite high: fishermen in Gujarat, India, for instance, took 591 whale sharks in 1999 and 2000, before whale shark hunting was banned nationally in 2001. Whale sharks often wind up in Asian markets, particularly in Taiwan, where they are known as "tofu sharks," for their soft, white flesh. There, the meat and fins fetch the highest price of any fish.

Signs of overfishing have already begun to appear. Whale shark catches have declined in several places that have been fished intensively. Meekan recently suggested that the Ningaloo Reef whale sharks are smaller by about six feet, on average, than they were a decade ago. Because they grow so slowly, reproduce so late, and congregate in small, migratory populations, whale sharks are particularly vulnerable to overfishing. Indeed, the World Conservation Union, a Switzerland-based environmental group, has listed them since 2000 as vulnerable to extinction.

Yet there are some hopeful signs, too. In the past decade several nations have banned whale shark hunting—though opportunistic capture appears to continue in some of those nations and elsewhere. Taiwan's fishery, perhaps the largest, persists with an official quota of sixty-five whale sharks per year. Still, it seems likely that the whale shark catch is lower than it was in the unregulated past, and several countries, such as the Philippines, have converted whale shark fishing centers into tourism destinations. Beginning in 2003, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (also known as CITES) imposed permit requirements on trade in whale shark products.

Just as encouraging has been the recent surge in scientific attention. Western Australia hosted the first International Whale Shark Conference in May 2005, bringing together scientists, resource managers, and conservationists from more than twenty nations. Perhaps the most valuable outcome of the meeting is still being played out, in the relationships and collaborations it nurtured among interested parties from around the world. If science can improve human understanding of the whale shark, future generations will be able to indulge the simple pleasure I have enjoyed—the chance to swim with the biggest fish in the sea. □

Life-size whale shark figures, made of bamboo and rice-sack cloth, are transported to a festival held each year in the Philippine fishing village of Donsol. The festival celebrates the arrival of whale sharks, or butanding, as they are known locally. Swimming with the protected whale sharks has become a popular tourist activity since 1998, when the animals were first discovered in the area.

The Worlds Behind the Glass

Museum dioramas create such a compelling "virtual reality" that visitors can forget the artifice and engage with nature itself.

By Stephen Christopher Quinn

From their very first appearance in science museums in the late 1800s, dioramas have been designed to nurture a reverence for nature. The best ones duplicate the wonder of an intimate, personal encounter with a real creature in its habitat. Many visitors come away transformed by the simulated wilderness world: A silverback mountain gorilla pounds its chest in a threatening display of dominance. An immense bull walrus rears up to survey its refuge on an Arctic ice floe. A giant brown bear stands in alarm before a panorama of spectacular Alaskan mountain peaks. Birds soar in suspended animation. Clouds hover motionless in azure blue skies. Behind the glass, time stops, and all of nature is locked in an instant for the viewer to examine.

Dioramas were born in an era when film and wildlife photography were in their infancy. In a sense, though, they leap ahead of those technologies to combine two- and three-dimensional elements into a form of "virtual reality." The classic habitat diorama is encased in an alcove with a windowlike frame or theaterlike proscenium that limits sight lines and conceals peripheral vanishing points. The scene itself is made up of three artistic components: taxidermy specimens; a foreground that encompasses all of the three-dimensional elements of the diorama other than the taxidermy; and the curved background painting, which is critical to the overall illusion of space, distance, and environment.

The American Museum of Natural History (AMNH) in New York City played a leading role in the development of the habitat diorama as a tool for science education. In its earliest years the museum's exhibition halls on zoology were made up of vast displays of its collections, with a focus on taxidermy specimens. But in time, the museum's visitors, curators, and scientists became dissatisfied with displays of specimens only. The view that nothing in nature originates in isolation, but comes instead out of complex interrelationships, also spurred the development of the habitat diorama.

The earliest dioramas at AMNH did not feature large, charismatic mammals, but rather depicted a

Libyan Desert diorama (left), at the American Museum of Natural History (AMNH), features three addaxes (far left), a scimitar-horned oryx (middle left), and a dama gazelle (near left). The "tie-in" between the foreground scene and the background painting has been cleverly disguised by the detailing of the shadows.

This article is adapted from Stephen Christopher Quinn's forthcoming book, Windows on Nature: The Great Habitat Dioramas of the American Museum of Natural History, *which is being published this month by Abrams, New York, in association with the American Museum of Natural History.*

more humble group of vertebrates: birds. In 1885, Morris K. Jesup, then president of the museum, was entranced by a British Museum exhibit of local birds, perched on botanical models of local plants. Jesup invited the artists responsible to come to New York to create a similar exhibit at AMNH. The result was a lifelike display of a pair of American robins nesting in the bough of a flowering apple tree.

The robin exhibit proved so popular that it easily generated funding for more. The early exhibits, known at the time as "habitat groups," were simple glass cases containing taxidermy specimens and botanical models. Frank M. Chapman, a young ornithologist, improved their design by including a painted background of the birds' habitat. In still later exhibits, the painted background was rendered on a curved surface.

It wasn't until the naturalist and taxidermist Carl Akeley embraced Chapman's approach of traveling to document each specific diorama that the diorama realized its most magnificent expression at the museum: a gallery dedicated to African wildlife. When the Akeley Hall of African Mammals finally opened in 1936, ten years after Akeley's death, the exhibition showcased the groundbreaking sculptural techniques he created for taxidermy, which are still in use today.

Crossing the threshold of the Akeley Hall, one enters a hushed, darkened theater that portrays the vanishing natural Eden of Africa. Twenty-eight luminous "windows" depict the natural world of the continent. The dioramas have eighteen-foot ceilings, and some are as deep as twenty-three feet. The windowpanes, thirteen feet high, are angled downward to deflect reflections downward and away from visitors' eyes—an ingenious innovation for the time. Inside the cases the "ground" is below the level of the visitor, enhancing the illusion that the scene drops off dramatically into an infinite space beyond.

Each scene is startlingly realistic, featuring one or more large African mammals. All around are the soil, plants, trees, and birds that share the animal's native habitat. A landscape mural curves behind the mounted specimens and the three-dimensional foreground, creating the impression of a limitless vista.

Nearly all of the dioramas in the hall presented their creators with artistic challenges related to the "tie-in"—the edge along which the foreground scene had to merge into the background painting to create the illusion of a seamless image. That hurdle was particularly demanding for the scene of the Libyan Desert [*see photograph on preceding two pages*]. Unlike other dioramas, in which dense vegetation conceals the point where foreground meets background, the desert scene depicts an open, flat vista with little to conceal the tie-in. So when the artist James Perry Wilson painted the background mural for the desert diorama, he depicted the scene at sunrise. With the sun low on the horizon, long horizontal shadows are cast across the landscape in the painted scene. Wilson also added a rock outcrop to his landscape on the far left [*not seen in the photograph*], which casts a long, prominent shadow across the scene, just above the tie-in. The shadow draws the viewer's eye away from the point where the foreground sand meets the painted background, thereby effectively disguising it.

Andros coral reef diorama (opposite page) at AMNH is the world's only double-decker diorama. On the mezzanine level, the viewer sees the reef as it appears above the water surface; on the lower level, the viewer sees the underwater habitat. When scientists and artists collected reference materials for the diorama, in 1924, scuba equipment had not been developed, so workers relied on an underwater diving apparatus (above left). Chris E. Olsen, a background artist for the diorama, made field sketches for the exhibit on location underwater (above right).

Most dioramas in the museum depict a real place, somewhere in the natural world. Hence the production required a costly—and often intrepid—expedition to the site, where extensive collections and field references were gathered. In 1923 the museum sent curator Roy Waldo Miner to scout a site for a diorama that would depict the diversity of life around a tropical coral reef. He chose the Andros reef in the Bahamas for its spectacular stands of elkhorn and staghorn coral and its rich abundance of tropical fish. The collecting team brought back forty tons of coral—including a single specimen weighing two tons—and reassembled it in its original configuration.

The era predated scuba diving, and so the artists and curators on the collecting expedition could not swim about freely. Instead, they descended to the seafloor in heavy diving helmets, weighted suits, and boots designed to keep them from floating to the surface. Air was pumped to their helmets through long hoses from a boat above. Chris E. Olsen, for instance, the artist who painted the background of the diorama, carried oil paints and a waterproof canvas stretched over a glass panel on a weighted easel, to capture the dappling and shimmering effects of light as it passed through the deep water [*see photograph at right on page 50*].

The Andros coral reef itself was a vibrant ecosystem when the diorama that depicts it was completed in 1935. Today, of course, with the many threats to coral reefs around the world, museum curators would never consider removing any of its coral for an educational display. Outbreaks of coral disease, sedimentation, overfishing, coral bleaching, and algal blooms have all contributed to the reefs' decline.

Alaska brown bear diorama (left), on display in the AMNH Hall of North American Mammals, beckons museum visitors with its heroic proportions. Robert Rockwell (above) first sculpted a life-size clay replica of the standing bear, then encased it in plaster. The plaster shell, once dried, was the mold for a papier-mâché mannequin on which the tanned skin of the bear was pasted and sewn into place.

By the late 1950s, the popularity of the diorama as an exhibit medium was on the wane. Television and film competed with the diorama as ways to "experience" nature. In the ensuing decades, interactive exhibits made possible by advances in computer technology pushed the diorama off the drawing board at many museums.

But the species was only dormant, not extinct. In recent years, the diorama has made something of a comeback, as exhibit designers have realized its power to give visitors an experience unattainable through any other medium: a compelling illusion of a place in nature, at life size and in real time.

In 1996 AMNH sent a team of artists and scientists to the Central African Republic to collect the reference material for its largest diorama, a replica of a tropical African rain forest. For the 2003 renovation of the Milstein Hall of Ocean Life, some of the museum's earliest dioramas were meticulously restored, such as the one showing the Andros coral reef. Other dioramas, such as the harbor seal, the elephant seal, and the stellar sea lion, were newly fabricated, from archival specimens collected long ago.

Although many people sometimes feel distanced from the natural world by civilization, museum dioramas remind us all that we still belong to it. They are an illusion created not to deceive, but—like all great art—to tug at our hearts and open our minds as they draw us in. They are the best way yet invented to accurately reflect, with art, the awe and wonder we feel before nature and the creatures with which we share the earth. Will we treasure the planet as we do the dioramas, or will they one day become museum pieces in the more pejorative sense, a record of a lost world, as it was before we defiled it? □

Alaska's Underground Frontier

An observatory that looks down—not up—at the planet's microbial diversity

By Christine Mlot

The workboat I'm riding whips down the Tanana River in the interior of Alaska, just west of Fairbanks. Rains in the past two weeks have made the Tanana high and swift in its rush to meet the Yukon River, on its way to the Bering Sea. Today is bright, with a ceaseless boreal sun and a breeze that keeps the mosquitoes at bay—a good day for summer fieldwork.

The boat stops along one of many side channels that make up this labyrinth of a river, and we unload on a small, thickly wooded island. Our gear is not high-tech: a couple of T-shaped soil corers, boxes of zippered plastic bags and latex gloves, a jar of ethanol. We hike into the brush and begin.

Most people come to Alaska for the big things: big mountains, big game, big fish. We have come for the little things. We are here to collect and study the bacteria that live in the cold, thin soil beds. Ecologists have been studying the succession of boreal forest at this site, the Bonanza Creek Experimental Forest [*see map on opposite page*], since the 1960s. (More recently the National Science Foundation, or NSF, has been funding the study as part of its Long-Term Ecological Research Network, which was established in 1980.) In the past few years the study has gone underground, literally, to explore the microbial communities on which the forest depends.

The small island—our first sampling site—is thick with balsam poplar. The trees represent an early stage in the centuries-long successional cycle of the forest. Heather K. Allen, a doctoral student who is writing her dissertation on the bacteria living here, clears the leafy duff and stabs a soil corer through a knot of roots and into the forest floor. Out comes the first of some eighty samples we'll collect today.

Collecting bacteria in the wild hasn't changed much since the days of the early microbe hunters, such as Louis Pasteur, 150 years ago. Preventing

Aerial view of the Tanana River, looking roughly south, shows some of its meandering course near Fairbanks, Alaska; the peak of Denali is visible on the horizon at the upper right. The braided river regularly creates new islands out of silt that can support forest life, with a little help from microorganisms.


ALASKA
Yukon River
Area of Detail
Alaska Range
Tanana River
Denali
Fairbanks
Bonanza Creek Experimental Forest
Tanana River
N
0
5
miles

contamination remains the main challenge: keeping the bacteria you want from mixing with all the other microorganisms in the environment and on yourself. What has changed dramatically in recent times is how the collected microorganisms are studied. Typically only a small fraction of the full microbial community grows in standard laboratory conditions. Look at a diluted speck of our Alaskan soil sample under a microscope, and you see a teeming world of rod- and sphere-shaped cells. Yet less than 1 percent of those cells take to life in a Petri dish. It could be compared to throwing a party, inviting a thousand people, and having only one person show his face. Microbiologists refer to the bacteria that don't show up in laboratories as "the uncultured majority."

The breakthrough in the study of this major slice of life came in the early 1980s, when microbiologists realized that microbial DNA could be extracted and read without culturing the organisms first. New molecular techniques for manipulating DNA have launched another age of exploration and discovery of the microbial world, with staggering results. It has become routine to find novel genes and exotic strains of microorganisms even in samples from rather ordinary habitats. Entirely new phyla are still being unearthed. In 1987 microbiologists recognized about a dozen bacterial phyla, all of which could be grown in a laboratory dish. Today at least fifty-three phyla are known, twenty-seven only through their DNA.

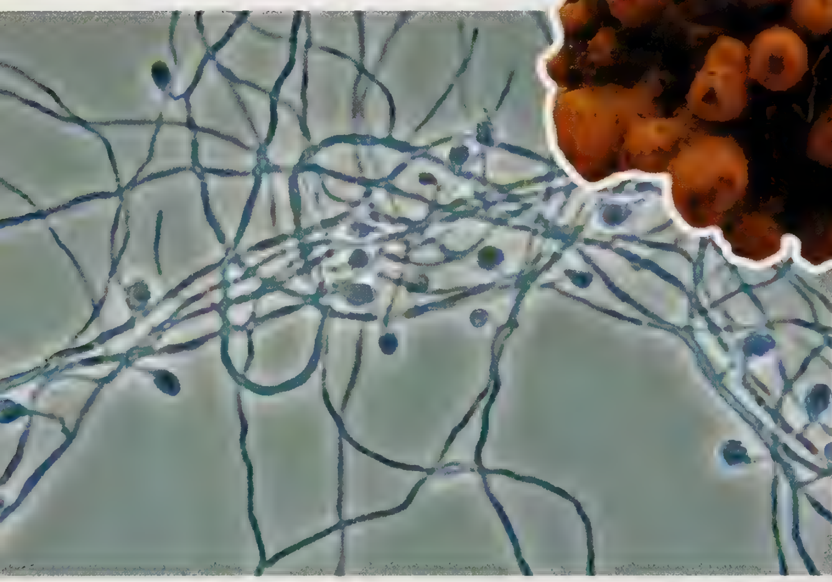
In other words, like pandas that won't breed in a zoo, the wild bacteria from those twenty-seven phyla have yet to be cultured in the laboratory. Perhaps they need biochemical compounds produced by other members of their microbial community, making it impossible for them to reproduce and multiply in pure cultures. Or perhaps the conditions in a Petri dish are too rich, compared with conditions in their natural habitats: A group of investigators at Oregon State University in Corvallis recently cultured a newly discovered, yet widespread, marine bacterium by growing it in little more than seawater.

The excavation of the enormous diversity in the microbial world is redesigning the tree of life. At the genetic level, plants and animals turn out to be mere twigs among a dense thicket of bacteria, archaea (the recently recognized third domain of life), and other kinds of microscopic organisms. The genetic studies are also changing the scientific understanding of the basic flow of elements through the environment. Microorganisms, after all, are the main gateway between the animate and inanimate—they can subsist on sludge, rock, or even toxic waste, and thereby open up a food chain.

To explore the hidden world, microbiologists have set up a network of some fifty "microbial observatories," such as the Bonanza Creek observatory in Alaska, to take a census of microorganisms living there. Scattered around the globe in a range of environments, the observatories have discovered thousands of novel microbial types, and even new biochemical pathways.

The Bonanza Creek observatory is distinguished by the unusual way in which local bacteria obtain the element phosphorus, which in turn enables the rest of the forest to grow. Work at the observatory is also turning up unusual antibiotics and other biochemicals produced in the cold. And this being Alaska, in the early years of the twenty-first century, the boreal site and its samples are becoming grist for the study of global-warming effects as well.

In the language of the native people of this land, the Athabascans, *tanana* suggests "mountain river." Run-off from glaciers in the Alaska Range—the mountains that include North America's highest peak, Denali—converges into streams that eventually form the Tanana. The river also carries debris from the glacier-scraped mountain range: a fine silt, which colors the water a concrete-dun. Word around Fairbanks is that if you fall into the Tanana, you must get



Frankia bacteria form nodules on the roots of an alder plant (upper right) and supply the alder with usable nitrogen in exchange for sugar. At the microscopic level (above) Frankia often grow in filaments that extend and branch out at the tips; they also develop vesicles, or round structures, where they process nitrogen from the air. The micrograph is magnified 1,100×.

out of your clothes fast, before they fill with the silt and drag you under.

But mountain silt brings life as well. Deposited onto sandbars along the river, the silt creates fresh real estate for water-loving willows and thin-leaf alder. Old and new islands in the river channel hold patches of the boreal forest at all stages of succession. Hopping from one island to the next, you can trace the evolution of forest life from the first colonizing plants to the oldest trees in the forest [*see illustration on next two pages*].

Growing a forest on islands of bare silt takes unusual chemistry and unique bacteria. Plants get carbon in the form of carbon dioxide from the air, but the rest of the nutrients they need come through their roots. The river washes some of these nutrients onto the sandbars and fertilizes the seedlings that blow in, wash in, or hitchhike ashore. But not all nutrients are available or present in a chemical form the plants can use directly. That's where bacteria, along with root-associated fungi, come in. In the soil, on or near the plants' roots, microorganisms retrieve and transform certain elements, thus enabling growth in nutrient-poor places.

Cankers pepper the trunk of an alder. The cankers are the result of a fungal infection that eventually kills plants by inhibiting nitrogen fixation.

Like many a backyard garden, the sandbars along the Tanana are poor in nitrogen—an element all plants need to build protein. Nitrogen is abundant in air, of course, but its atmospheric form (the molecule N_2) is useless to plants. Certain bacteria in the genus *Frankia*, however, make enzymes that enable the bacteria to retrieve molecular nitrogen in the air. Those bacteria are symbiotic with alder, living in nodules on the plants' roots [*see images on opposite page*]. The bacteria provide the alder—and ultimately the forest—with usable nitrogen in exchange for sugar synthesized by the plant. As our guide and collaborator, Roger Ruess, an ecologist at the University of Alaska in Fairbanks, puts it: "The plant has to support the drug habits of *Frankia*."

Both the alder plant and *Frankia* seek another element that is in short supply: phosphorus. The element is needed to make DNA, among other molecules, and limits how much nitrogen the *Frankia* can fix, or change into a form usable by the plant. When phosphate—a molecule in which one phosphorus atom is bound to four oxygen atoms—is experimentally added to a site, the rate of nitrogen fixation shoots up, along with the plant's growth. Phosphorus is naturally present in the soil, but, like atmospheric nitrogen, it is locked up in chemical forms plants cannot use.

Yet the bacteria living along the Tanana manage to obtain some of the otherwise unavailable phosphorus. William W. Metcalf, a microbiologist at the University of Illinois in Urbana, and his students have assessed Tanana soil bacteria for certain DNA sequences and discovered that a high proportion of them possess enzymes—only recently discovered—that can metabolize the locked-up forms of phosphorus. Most organisms must get their phosphorus from phosphate, its most common state, but some bacteria we collected on the Tanana can convert "reduced" forms of phosphorus, such as the phosphite molecule (one phosphorous atom bound to three oxygen atoms), into phosphate. Fed only those reduced forms of phosphorus in the laboratory, bacteria from the river site grow just fine.

By growing with the captured phosphorus, the collaborating alder plants, bacteria, and fungi help open the way for other forest denizens. Investigators find that alder improves the nutrition of neighboring plants and soon attracts wildlife. Hare and moose have obviously browsed the willow bushes on the riverbank where we pause for our lunch.

Animals rarely like to eat alder, but lately it's become lunch for something else. Last year investigators noticed that cankers, caused by a fungal pathogen, were appearing on the alders [*see photograph above*]. Now they are watching intently to see how the lesions may affect the forest at this pivotal, early stage of its development. The fungal infection decreases the rate of nitrogen fixation and eventually kills the alder. Will enough of the population succumb to alter the normal succession of the forest? No one knows, but at some sites along the Tanana, cankers have appeared on as many as 80 percent of the alders.

We see pimply bark, signs of the canker disease, at our first sampling site and elsewhere as we motor up and down the river to the various islands. The responsible pathogen may be the same fungus that

biologists have discovered attacking alder in Colorado, *Valsa melanodiscus.*

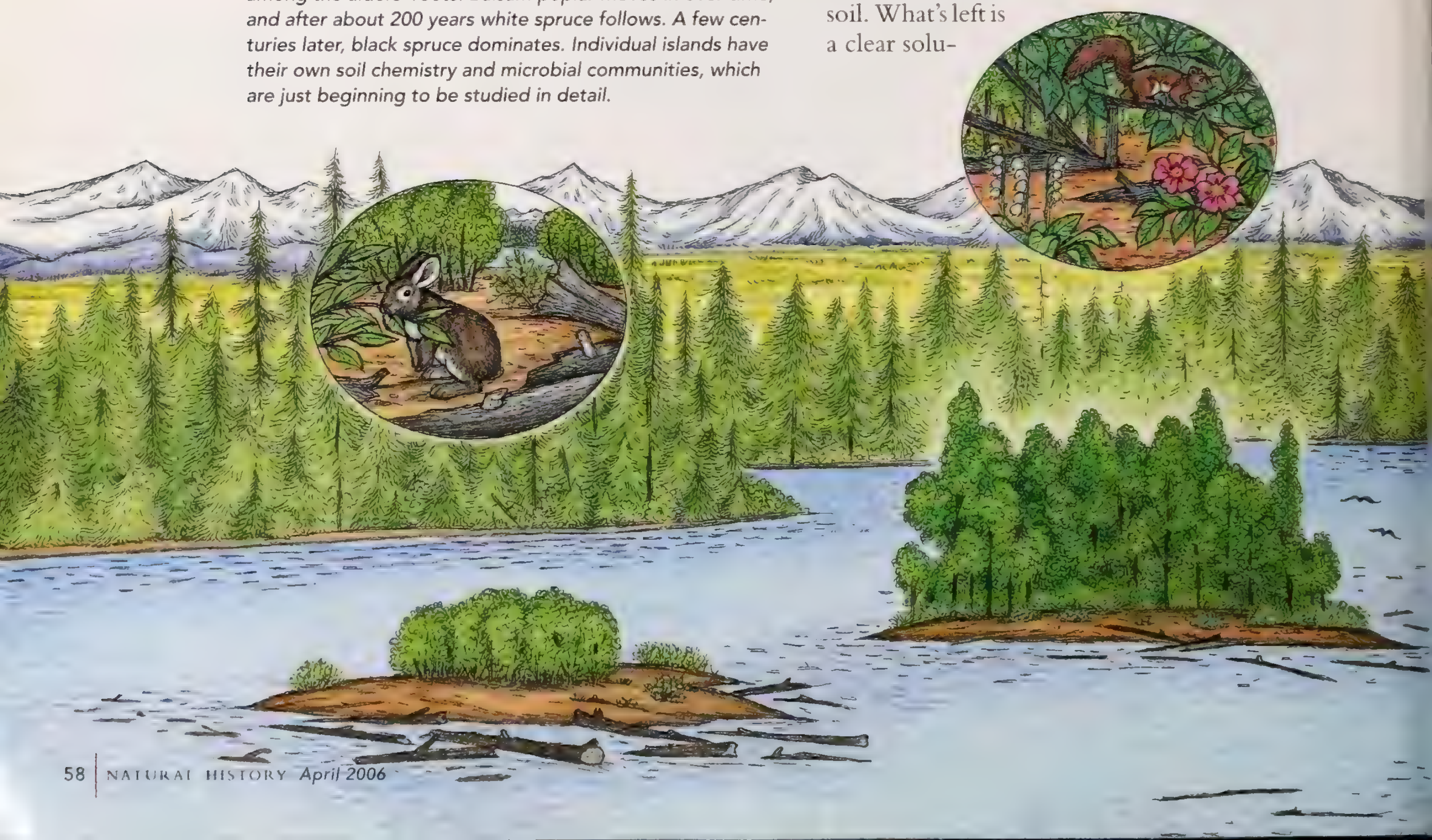
In spite of the alder canker, it's still possible to trace the normal forest succession along the Tanana. We pass by young sandbars thick with knee-high willow, and only an occasional shoot of alder. If the alder remains canker-free, it will grow like lilac bushes and crowd out the willow, dominating the small, sandy islands. Eventually, if the forest grows unimpeded, balsam poplar—also known as cottonwood in the Lower 48—shades over the alder and replaces it. Balsam poplar sheds its seeds in fluffy blossoms that litter the forest floor; our sampling sites are full of them, along with thickets of prickly rose and sprigs of pyrola, or wintergreen.

At another island upstream, we enter a fragrant cathedral of 200-year-old white spruce: the next stage of the forest succession. The brushy groundcover of the balsam sites has given way to green lichens, cushiony mosses, and more legroom. The recent rain has prompted a show of mushrooms, too. We find the wild relative of the common white button mushroom *(Lycoperdon)* and a burnt-marshmallow look-alike *(Sarcodon imbricatum).*

Up and across the river we sample the bacteria that live in the final stage of forest succession. It is the coolest stage, both literally and figuratively. Black spruce trees jut like pipe cleaners amid an aromatic groundcover of Labrador tea, low-bush cranberry, and more mosses. The accumulation of feathery moss has by now insulated the ground, preventing it from warming during summer, and so a permafrost layer begins as little as a foot beneath the surface. We pull samples of fibrous soil the color of chocolate cake out of the ground, as cold to the touch as if it came out of a cooler, rich with the complex smells of soil. The smells themselves are signals of bacteria: the vapors of volatile compounds released by *Streptomyces* bacteria, the source of streptomycin and other antibiotics. A billion bacterial cells, representing thousands of different strains, can live in a teaspoon of the soil, along with perhaps dozens of fungal strains.

Stored in coolers, the soil samples get shipped to Jo Handelsman's microbiology laboratory at the University of Wisconsin–Madison. There, a small crew of investigators starts in on the work. Most of the soil ends up being processed into "libraries" of DNA, the better to explore and analyze the vast world of yet-uncultured microbial diversity.

To create the libraries, pinches of soil are tucked into inch-deep tubes. Minute synthetic beads are added to break open the bacterial cells as the tubes spin in a centrifuge. Solutions are used to wash the burst DNA and separate it from the rest of the compounds in the soil. What's left is a clear solu-



Forest succession (left to right) along the Tanana River begins as the first colonizers, willow and then alder bushes, get nitrogen with the help of Frankia *bacteria that live among the alders' roots. Balsam poplar moves in over time, and after about 200 years white spruce follows. A few centuries later, black spruce dominates. Individual islands have their own soil chemistry and microbial communities, which are just beginning to be studied in detail.*

tion containing the bacterial DNA—a proxy for the original community.

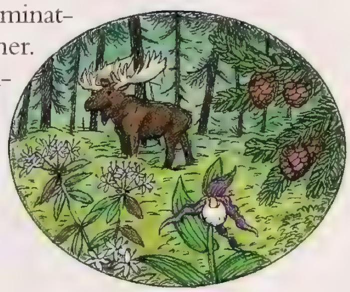
One particular gene, or stretch of the DNA, serves as a universal bar code that identifies each of the bacterial strains present in the soil. Fishing out and sequencing the many versions of this bar-code gene and comparing them with similar, yet known, sequences in gene databases reveals the identities and relative abundances of the various microorganisms. It also shows where the microorganisms from the Tanana River site belong in the bacterial family tree.

The identity of a microorganism is largely a matter of what it can do, and those functions are, in turn, a matter of the kinds of proteins the microorganism produces. To find out what proteins the Tanana soil bacteria produce, the DNA extracted in the laboratory is converted, in a controlled way, into the proteins it codes for, and the proteins are assessed for various functions. Typically, the extracted DNA is mixed with enzymes that cut it into pieces. The pieces are then inserted into other bacteria, such as the laboratory workhorse *Escherichia coli*. Once inside *E. coli,* they are processed into protein just as if they were part of *E. coli*'s own DNA. Functionally analyzing the new protein is then just a matter of testing the genetically altered *E. coli*. For example, if the genetically altered *E. coli* can grow on an antibiotic that would kill ordinary *E. coli,* the inserted DNA must have carried a gene for a protein that somehow disables the antibiotic.

We also study the Tanana soil microorganisms in a more traditional way: cultured on a Petri plate. When we compare what can be grown using different nutrient sources and growing conditions with what we know is present from the soil DNA, the cultural divide is stark. Bacteria from nineteen different phyla live in the Tanana samples, yet we can grow representatives from only four.

Microbiologists are sometimes fond of saying, "Everything is everywhere." In other words, bacteria are distributed globally. But as the bacterial census-taking continues, the exceptions, such as our "mountain river" microorganisms, keep surfacing.

The Tanana soils seem to be something of a microbial backwater. We have to look hard to find any *Bacillus,* one of the most common soil bacteria anywhere. Even soil samples from distinct sites on the same Tanana island, or from the same site but just a few inches apart in depth, have different characters—like Scottish villages dominated by one clan or another.



Although all the sampling sites in balsam-poplar forest look sim-

ilar to our eyes, one of them turns out to be a hotbed of a particular kind of antibiotic-producing bacteria *(Janthinobacterium)*. They've become a laboratory favorite because of the bloody crimson and inky purple pigments they produce—but only at cool temperatures [*see photographs on this page*]. Whatever the function of the pigments turns out to be, it seems likely that the Alaskan bacteria have developed storage compounds, communication signals, and other specialized biochemicals adapted to their high-latitude life.

Newfound strains of Janthinobacterium from soil in Alaska's boreal forest form nondescript colonies at warm temperatures (above), but start to produce red and purple pigments, along with antibiotics, at cold temperatures (below right).

The emphasis of the microbial observatories is on understanding microbial diversity, but they are also on the lookout for new drugs or other useful chemicals that the microorganisms might produce. The Tanana soil bacteria, for instance, thrive in cold and phosphorus-limited conditions. Perhaps they make proteins that could be useful in agriculture, medicine, or even laundry—a bacterial enzyme that can operate in cold, boreal soil might be able to improve the stain-removing power of cold-water detergents.

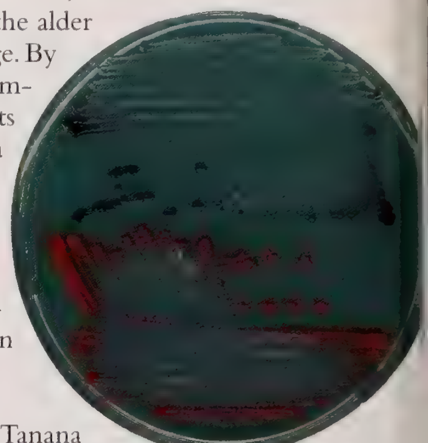
But are conditions still cold? It's hard to escape what many read as signs of unusual warming at these latitudes. We sniff smoke in the air, blown in from a forest fire in the Yukon. By the end of summer 2005, the fire season has become Alaska's third worst. And the all-time worst was just the year before that: in 2004, fires consumed 6.5 million acres of Alaska, an area bigger than Vermont. On average, the state is two degrees Celsius warmer than it was at the beginning of the twentieth century. The average surface temperature of the Earth has warmed by one-fourth that amount (a half degree Celsius) in roughly the same period.

Making a direct, causal link between the warming trend and changes on the ground is hard to do, but investigators in Alaska have tallied a compelling list of consistent phenomena. In addition to the record fires, the growing season has lengthened, while, paradoxically, the oil-drilling season has shortened by about half (the tundra in the far north must be frozen deep enough to support the heavy rigs and traffic). Sea ice is also dramatically diminished; it reached a record low of 2 million square miles in 2005. The melting of sea ice—about 400,000 square miles in the past decade or so—amplifies climate warming and its myriad effects, as open water absorbs heat that the ice would otherwise reflect back into space.

Insects such as spruce bark beetles, which historically have taken two summers to mature, now come of age in one, creating explosive populations that have chewed up temperature-stressed trees. Could the alder canker be another effect of the stress on plants? It's possible. This is clearly uncharted territory in the life of the boreal forest.

At the Bonanza Creek Experimental Forest and microbial observatory, soil temperatures have ratcheted up to such an extent in the past twenty years that the mean annual temperature half a foot below the surface is now above freezing. The warmer soil affects the forest community and its microbial underpinnings in yet-uncharted ways, and it affects the global carbon cycle as well. As permafrost thaws, the prediction goes, microbial decomposers gain a huge new source of organic material to consume. But how well the little-known microbial communities will hew to the prediction, and how much carbon could be released from this historical carbon sink, remain to be seen.

What microbiologists do know is that the changes both above and below the ground will alter the microbial community in subtle ways. Inevitably, one strain or another will outgrow the rest. If the "winner" happens to be a microorganism with a knack for virulent infection, more pathogens such as the alder canker could emerge. By taking yearly soil samples, microbiologists are accumulating a DNA record of the microbial communities that might come to reflect the changing temperature and vegetation of the sites.



North of the Tanana River, gentle bluffs border the floodplain. To the south, the wall of the Alaska Range lies obscured in haze. In between, the braided river takes the path of least resistance through the valley, creating the many rivulets and side channels in its seaward push. In spite of the seemingly timeless majesty of the place, everything in this panorama is moving: the river, the mountains, and the forest in all its stages. The lives of the cells in the soil are shifting, too. Too little is known of this complex and unseen world to begin to predict what will become of it—too little, that is, except that it will bring surprises. □

THIS LAND

Green Fingers

A woodland revives among the glacier-carved lakes of central New York.

By Robert H. Mohlenbrock

Mayapples rouse themselves in early spring beneath young sugar maple trees.

In 1891 President Benjamin Harrison signed legislation authorizing the establishment of national forests in the United States. Since that time, 155 national forests have been designated, scattered within the boundaries of forty-four states, Puerto Rico, and the Virgin Islands. Some of the forests preserve areas in conditions so pristine they compare well with the state of the lands in the national parks. Others encompass land degraded by earlier human occupation, which was then restored through reforestation and good forest management. The most recent member of the group, added in 1985, is Finger Lakes National Forest, situated on a ridge known as Hector Backbone. The ridge lies between the southern ends of Seneca and Cayuga lakes, the two largest of the Finger Lakes in west-central New York.

White trillium

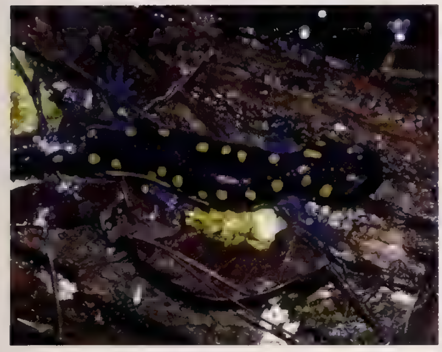
The scenic Finger Lakes are named for eleven long, narrow lakes that run roughly north-south along nearly parallel lines. The lakebeds were formed during the past two million years by southward-moving glaciers, some more than two miles thick, which carved deep crevasses into the old valleys of northward-flowing rivers. After the last glaciers began their retreat, about 19,000 years ago, they left behind the lakes and the elongated ridges, known as drumlins, that separate them (Hector Backbone is one of those drumlins). The glaciers also left gravel deposits called moraines at the southern ends of the lakes.

The region was home to Indians of the Iroquois Confederacy until 1779, when they were evicted under orders of General George Washington because four of the six nations in the league had allied themselves with the British. The land that was seized was then allotted to soldiers and veterans of the Revolutionary War, as payment for their service. The settlers on Hector Backbone produced hay and small grains, such as buckwheat, for sale in New York City. But the combination of a poor post–Civil War economy, westward expansion, changing access to markets, and hard-to-work soils led to the abandonment of most farming there in the 1890s and the early decades of the twentieth century.

In 1934 the federal government began to acquire land on Hector Backbone and started a program of reforestation and the creation of artificial ponds. Because the owners were under no obligation to sell, the

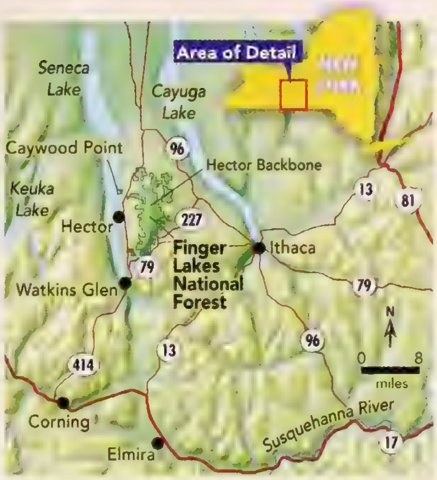
area became the patchwork of federal and private lands that characterizes it to this day.

Covering twenty-five square miles, Finger Lakes National Forest includes pastoral woodlands brightened in the spring by numerous wildflowers and azaleas and, in the fall, by the autumn foliage of American beeches, birches, red maples, and sugar maples. County roads form the western and northern boundaries of the forest, and New York State routes 79 and 227 lie along its southeastern side. Trails for hiking and horseback riding, as well as several black-top and gravel town roads, crisscross it as well, offering easy access. The Blueberry Patch Campground provides facilities for camping and picnicking. Groups can use the Potomac Group Campground; the Backbone Campground is open to equestrians. One parcel of the forest even offers Seneca Lake frontage on what is called Caywood Point.



Spotted salamander

My favorite trail, which gives a good cross section of the natural features, is one of the shorter ones: Gorge Trail. Not far from the parking area where it begins, the trail passes Gorge Pond on the left. A marshy habitat with a diverse array of wetland plant species extends from the pond to the edge of the trail. To the right is a dry woodland. Farther along, the trail gradually descends into a narrow valley—the gorge—and the woods become more moist.



VISITOR INFORMATION

Finger Lakes National Forest
5218 State Route 414
Hector, NY 14841
607-546-4470
www.fs.fed.us/r9/gmfl/fingerlakes

ROBERT H. MOHLENBROCK is a distinguished professor emeritus of plant biology at Southern Illinois University Carbondale.

Habitats

Woods The tallest trees include American beech, basswood, black gum, black walnut, northern red oak, red maple, shagbark hickory, slippery elm, sugar maple, white ash, white oak, white pine, and yellow birch. Shorter trees scattered throughout the woods are arrowwood, common elder, hop hornbeam, maple-leaved viburnum, musclewood, and witch hazel. Riverbank grape, a vine, climbs high up many of the tree trunks and branches.

Among the more common ferns in the understory are Christmas fern, lady fern, New York fern, and spinulose wood fern; sensitive fern occupies the wetter areas. Spring wildflowers include false Solomon's-seal, hooked crowfoot, jack-in-the-pulpit, lady's slipper, mayapple, red columbine, starflower, tall white beardtongue, white avens, white trillium, and wild geranium. During late summer and autumn, flowering species include common enchanter's nightshade, downy pagoda plant, hog peanut, roadside agrimony, wrinkle-leaved goldenrod, and two kinds of little white asters. In wet areas are scattered attractive white turtlehead plants.

Pond Submerged aquatic plants such as brittle water nymph, coontail, sago pondweed, and waterweed grow in most ponds. The muddy shorelines support strawstem beggar-ticks, bristly sedge, bur reed, common spike rush, gray dogwood, narrow-leaved cattail, needle spike rush, pussy willow, soft rush, wool grass, and many other species.

Marsh Among the marsh plants are bluntleaf bedstraw, common flat-topped goldenrod, fowl manna grass, purple-stem aster, sensitive fern, smooth goldenrod, spotted joe-pye weed, rice cut-grass, rough-leaved goldenrod, and tall flat-topped white aster. Scrambling over the vegetation is bittersweet nightshade, a nonnative species that pioneers planted for its pretty purple flowers, bright red berries, and intriguing leaves (they have one large lobe in the middle and two small lobes near the base).

Open areas Fields that are no longer cultivated, roadsides, and trails provide open habitats. Many of the plants that grow here are invasive species from Europe and Asia, such as bouncing Bet, common yarrow, garlic mustard, hairy woodland brome, Japanese honeysuckle, multiflora rose, musk mallow, ox-eye daisy, and self-heal. Among the native species are bitter dock, common blackberry, common cinquefoil, common goldenrod, common yellow wood sorrel, hairy white oldfield aster, hemp dogbane, path rush, and staghorn sumac.

By Laurence A. Marschall

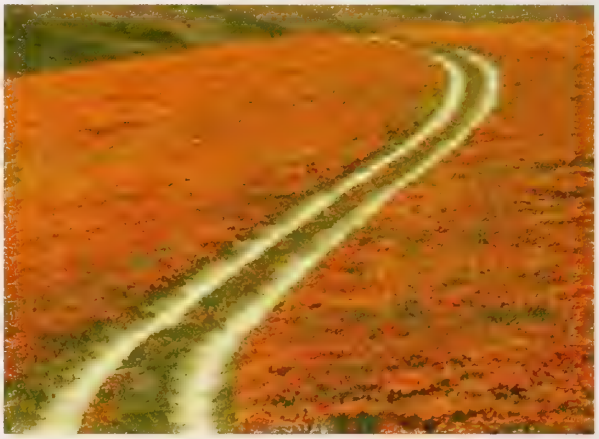
Chasing Spring: An American Journey Through a Changing Season
by Bruce Stutz
Scribner, 2006; $24.00

At the beginning of this spring-chasing journey, set in 2004, neither Bruce Stutz nor his automobile is a good bet to finish a three-month odyssey across the continent and up to Alaska. Stutz, a former editor-in-chief of this magazine, has recovered recently from surgery for a faulty heart valve. Dick (named after Moby), a 1984 white Chevy Impala, still has its original valves, but twenty years of gathering dust in the garage of a friend's mother have not been kind. Both man and car need to get on the road again and get their fluids running. And what better way to revive than to follow spring, the season of rebirth, as it sweeps across North America?

Stutz's journey is a long one, though hardly epochal. It begins on the vernal equinox, north of New York City, and ends when the Sun touches the horizon at midnight, at summer solstice, on the Arctic Circle. Along the way he stops to witness how the environment is changing, and to chat with scientists who study it.

There are plenty of changes to ponder. While still close to his home in Brooklyn, he accompanies a biologist to a seasonal vernal pool, helping to survey frogs and salamanders. The experience gives him ground truth about the threat suburban development poses to the creatures' woodland habitats. Passing through North Carolina, he visits an experimental forest where PVC pipes, sixty feet high, circle seven large stands of trees. To measure the effects of greenhouse gases on forest growth, holes drilled in the pipes blow varying amounts of carbon dioxide or plain air over each stand, while fieldworkers assiduously plot the effects on the trees.

Two weeks later, in Oracle, Arizona, Stutz visits Biosphere 2, a giant glass terrarium. Completed in 1991, it houses a 700,000-gallon artificial ocean, a coral reef, a rainforest, a mangrove swamp, and a desert. Nowadays the place has fallen on hard times. All the delicate elements designed to balance its enclosed ecosystem are limping along and beginning to fail. Stutz suspects that Biosphere 2 may unintentionally, in its decline, have become the accurate microcosm for the larger ecosystem it was intended to model—Biosphere 1, planet Earth.



Country lane leads the traveler through a field of poppies in California.

And so it goes. Passing through Tornado Alley in Oklahoma, Stutz continues on to the Colorado Rockies, to join a group of environmental scientists who gauge climate warming by monitoring the depths of spring snow. Then, in Oregon, he meets a group of peripatetic hunter-gatherers who make their living collecting mushrooms for sale. They seem to keep at it, in an uncertain market, just because they like the outdoor life. By early June, Stutz and Dick have reached Glacier National Park, where the largest of the huge ice rivers that gave the place its name covers only 10 percent of what it covered in 1850.

With Dick resting safely in a parking lot at the Seattle airport, Stutz ends his journey in the Arctic National Wildlife Refuge. That's about as far north as one can get in the United States. Glad to be there as the last rays of vernal sun kiss the thawing permafrost, Stutz realizes that he's come through a season of change, in life as well as on Earth, and that many of the places he's visited he will probably not see again.

Armchair travelers who join Stutz through this pleasant journal will be glad they came along, but they, like the author, may also share his unease with the changes that are not merely seasonal, but long-term. Too many changes seem wrought, in part, by inattentive stewardship. "What will your and my children's and grandchildren's springs be like?" he asks at the end. "Will [our children] be able to head out in spring to recover their hearts?"

Parenting for Primates
by Harriet J. Smith
Harvard University Press, 2006; $29.95

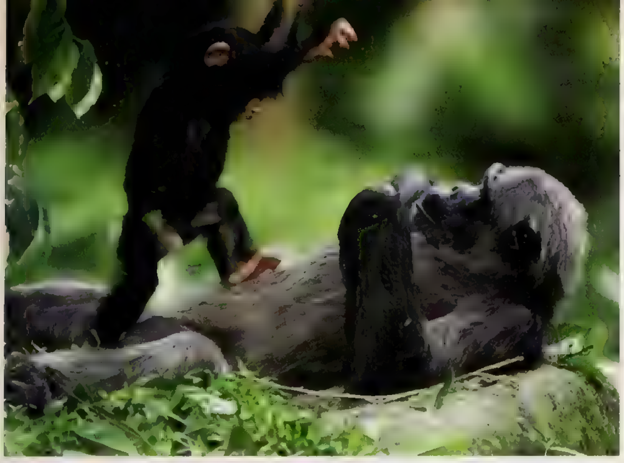
Dear Harriet:
My son Carl, who is eight, just can't seem to sleep alone. It's gotten worse since Cindy, my youngest, was born. Needless to say, I have to keep Cindy close, since she's suckling, but Carl keeps interfering, snuggling up to us every night when we need time to ourselves. What should I do to get him to grow up and let us rest in peace?

[Signed] *Cara* [her mark]

Dear Cara:
Carl is just feeling a natural anxiety at being weaned from co-sleeping. Build yourself another nest. When it's done, bed down in that old nest, and once Carl's asleep, move with Cindy to the new nest. Carl may be upset, but after you've repeatedly left him alone in the old nest, he'll get the idea. He may even decide to build his own nest. It's worked for other orangutans, in my experience, and it will be good preparation for his adolescence, when you inevitably kick him out!

Yours groomingly, Harriet

Of all the primates, people have by far the most complex and most enduring relations with their offspring. Yet we humans share more than just a



Primate parent and offspring

common ancestry with apes, monkeys, and lemurs. All primates have a rich social life and face similar problems in raising their offspring. All primate parents must provide food, protection, and education to their young. All face questions of how and when to wean babies from the breast, how to get youngsters to take care of themselves and relate to others, how to let them know it's time to go off on their own. Just as people must ensure that Johnny can read, chimpanzees must teach their youngsters to find the best-tasting termites.

Harriet J. Smith brings impressive credentials to the writing of this fascinating book on comparative parenting. A clinical psychologist in family practice and the mother of two human females, she also holds a Ph.D. in comparative psychology and has raised several generations of cottontop tamarin monkeys in her backyard. Although the book includes a few examples from Smith's therapeutic files (with the names changed, of course), she draws mostly from an impressive variety of anthropological and zoological studies of groups ranging from hunter-gatherers in the Philippines to gorillas in Africa and red howler monkeys in the jungles of Venezuela.

As one might imagine, parenting styles among primates vary as widely as they do among human cultures. Marmoset dads in Central and South America, for instance, are loving fathers and share in infant care. Silverback gorillas, though affectionate and concerned, keep pretty much to themselves, offering protection to their families but little parental help or guidance. And female orangutans in the forests of Borneo are paradigmatically doting single mothers: they raise an average of three offspring during their lifetime, devoting years to each one without the slightest help.

Smith's thought-provoking book, despite its partial genesis in her family practice, is not intended as a guide to effective child rearing. But I'd recommend it to any parent or prospective parent, with this caveat: What's good for a tarsier or a lemur may be dysfunctional for a gibbon, a macaque—or a human.

The Electric Life of Michael Faraday
by Alan Hirshfeld
Walker and Company 2006; $24.00

The twenty-first century would not exist as we know it were it not for a nineteenth-century English experimenter named Michael Faraday. Lest that assessment seem hyperbolic, consider that until the 1820s, when Faraday devised a way to make electricity rotate a metal rod, all the world's work had been done by steam, water, animal, or human power. Faraday's rotating rod led to the modern electric motor, the cornerstone of our modern electrified world.

His demonstration, a decade later, that a varying magnetic field could induce an electric current in a coil of wire is the principle behind the electric generator, which provided the power to run those electric motors. In time, Faraday's inventions and their direct descendants found their way into every electric power plant, every automobile alternator, every air conditioner, garbage disposal unit, and DVD player—in short, into virtually every aspect of modern technological society.

That is quite a legacy from a man whose meager formal education was supplemented by only a few years apprenticed to a bookbinder. Even when Faraday was an honored figure at England's Royal Institution of Great Britain in London, his salary never exceeded a few hundred pounds a year. As Alan Hirshfeld's sparkling new biography makes clear, Faraday's influence stemmed not from learning or wealth, but from a rich imagination, a brilliance at experimentation, and an openness of character that won friends instantly and made him one of the outstanding scientific teachers of his century.

When the English chemist Sir Humphry Davy summoned Faraday (who had attended some of Davy's lectures) to join Davy at the Royal Institution in 1813, Davy must have sensed some of those qualities. The young Faraday quickly rose from glorified bottle-washer to full collaborator in the most difficult of distillations and preparations. Within a few years he was publishing his own papers and giving his own lectures to learned societies. By 1824 he had been voted into the prestigious Royal Society.

Beginning in 1826, partly to raise

Magneto-spark apparatus, now in the Royal Institution in London, was designed by Michael Faraday to generate an electric spark.

money for the laboratory of the Royal Institution, Faraday began giving a series of public lectures. The so-called Friday Discourses (which continue to this day) featured many of the notable scientists of the era: John Dalton, Lord Kelvin, Charles Lyell. But Faraday set the standard for clarity and showmanship. "It waked the young from their visions and the old from their dreams," gushed an admirer. Part of his success with the public stemmed from his memorable demonstrations of the latest discoveries. He detonated a hydrogen-filled balloon with an electric spark. He made his hair stand on end with a static-electricity generator. His favorite appearances, though, were the annual Christmas lectures he gave to children. No less a figure than Charles Dickens found them so impressive that he implored Faraday to turn them into an instructional book for children.

Yet for all of Faraday's brilliance in the laboratory and the lecture hall, many of his colleagues didn't know what to make of him. Untutored in mathematics, he could not express his results in the abstract notation expected by scholars. In his later years he developed an elaborate theory of electricity and magnetism based on invisible "lines of force" emanating from charged atoms. The theory was so visual, so based on imagery, that he was widely viewed as loony, or at least past his prime. Ultimately James Clerk Maxwell cast Faraday's geometrical ideas about lines of force into the mathematical framework now known as field theory—one of the underpinnings of electromagnetism, gravitation, and quantum mechanics. Faraday's theory turned out to be as self-descriptive as it was precocious: his own field of influence, like that of an electrically charged body, extended outward, effectively without limit.

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nature.net

New Moon

By Robert Anderson

The Moon reveals just one side to its admirers on Earth, yet our satellite seems an object with a thousand faces. It smiles with romantic light and winks at armchair space travelers. For me, most of all, it is the place where the *Apollo 11* astronauts set foot in 1969, when I was eight. But as an adult, I also see it as our planet's dynamic partner, without which life on Earth would never have flourished. Isaac Asimov's "Triumph of the Moon" (at mountainman.com.au/i_asimov.html), written shortly after he watched the launch of *Apollo 17*, sets forth his reasons for thinking we would not have evolved without the Moon, and how the Moon was crucial to the development of mathematics, science, and space travel.

The Moon, as the leading theory goes, was born in the aftermath of a titanic collision between a Mars-size planet named Theia and the early Earth. A Web page at the Planetary Science Institute introduces the "giant impact" hypothesis with paintings by William K. Hartmann, one of the astronomers who originated the idea in 1975 (psi.edu/projects/moon/moon.html). Alistair G.W. Cameron, another pioneer in the study of giant impacts, has a site at xtec.es/recursos/astronom/moon/camerone.htm with a number of his early computer simulations of the collision.

Collision theories also enliven Web pages by G. Jeffrey Taylor of the Hawai'i Institute of Geophysics and Planetology (www.psrd.hawaii.edu/Dec98/OriginEarthMoon.html) and H. Jay Melosh of the University of Arizona in Tucson (www.lpl.arizona.edu/outreach/origin). Their simulations show lighter mantle rock from both bodies blasted into orbit, while Theia's dense iron core merges with that of the proto-Earth to form our planet's present massive core. That core was key to life's overwhelming success: a smaller core could not have generated a magnetic field strong enough to shield us from lethal cosmic rays. Furthermore, the internal heat of our planet's enlarged core has been the driving force of plate tectonics, another likely prerequisite for complex life to evolve.

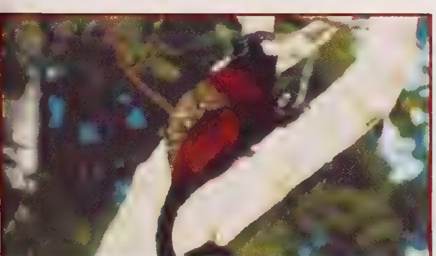
At the Internet encyclopedia Wikipedia (en.wikipedia.org/wiki/Giant_impact theory), an animation at the bottom of the Web page shows how Theia may have formed in the same orbit as Earth, at what is called a Lagrange point, before it drifted into us at a suitably low speed. Edward Belbruno and J. Richard Gott III calculated that this mechanism increases the likelihood of such planet-size impacts. While looking for more about Lagrange points, I came across a Web page on the topic by John C. Baez, a mathematical physicist at the University of California, Riverside (math.ucr.edu/home/baez/lagrange.html). In his section titled "Mars Trojans, Neptune Trojans, and Earth's strange companions," I was surprised to learn that Earth has several other "moons" tagging along. Relative to our planet, asteroid 3753 Cruithne, for instance, moves in a complicated spiraling orbit whose extremities resemble horseshoes.

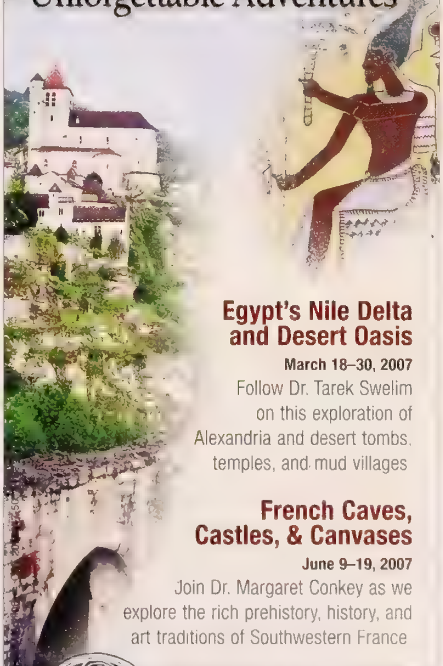
On the Internet you can find many new faces of the Moon, but I still enjoy the images the astronauts brought back almost four decades ago. At the Lunar and Planetary Institute Web site (www.lpi.usra.edu/resources/apollo), click on "70 mm Hasselblad" to view a complete collection of the ultimate tourist snapshots. Who is not still amazed by the images of Earth, rising moonlike over that barren surface? In the next few years, new lunar missions may be added to the old. Go to the lunar exploration page of the Goddard Space Flight Center (nssdc.gsfc.nasa.gov/planetary/lunar/apollo_25th.html) for a chronology of lunar exploration past, present, and future.

ROBERT ANDERSON is a freelance science writer living in Los Angeles.

EXPLORER GUIDE

EXPLORER GUIDE

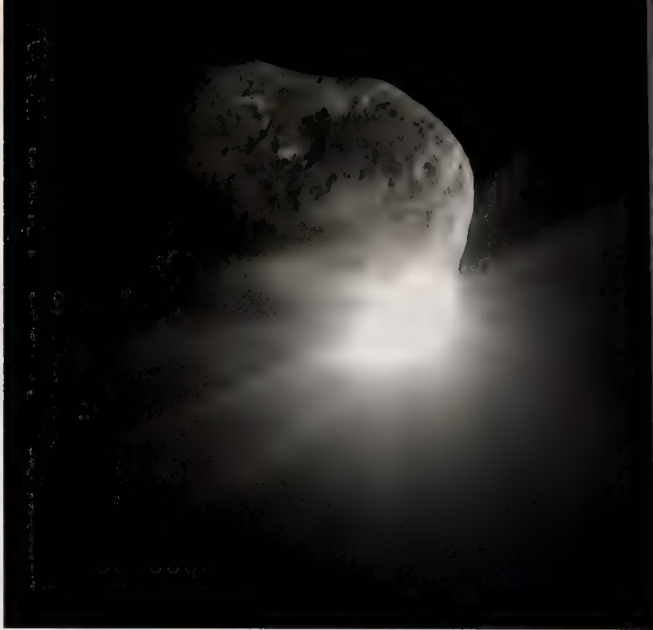




Crash!

A close encounter of the cometary kind

By Charles Liu



Comet 9P/Tempel 1 is pictured sixty-seven seconds after Deep Impact's impactor was intentionally crashed into it at 20,000 miles per hour. The collision created a bright burst of light at the point of impact. The photograph was made by the main Deep Impact spacecraft.

The term "astrogeology" (from the Greek for "star" and "earth") is either an overgeneralization or an oxymoron. If you're an astrogeologist, do you study Earth, or the universe beyond Earth, or both? And if you study both, what else is left? So, let's avoid the paradox by defining astrogeology as the study of cosmic objects with the methods and tools developed for studying our own planet.

It's easy to see the attraction of this rapidly growing subfield of astronomy. What rock hound wouldn't love to chisel into a Martian mountain or crack open a geode on Ganymede? And truly dedicated astrogeologists aren't about to be deterred by something so mundane as, say, a multimillion-mile commute. With scientific ingenuity, no stone is too far out in the solar system to stay unturned.

Maybe the most explosive example of astrogeological research so far is the Deep Impact mission, led by Michael F. A'Hearn, an astronomer at the University of Maryland in College Park. On July 3, 2005, the *Deep Impact* space probe released an 800-pound, battery-powered "smart impactor" the size of a washing machine into the path of Comet 9P/Tempel 1, then some 80 million miles from Earth. Twenty-four hours later, cameras on probe and projectile, as well as elsewhere in space and on Earth, snapped away as comet and impactor barreled toward each other at more than 20,000 miles an hour. Then, caught on images that will be analyzed for years to come, came the ultimate Independence Day fireworks.

The energy of the crash, which pulverized the impactor into a fine coppery mist, was like detonating nearly five tons of TNT or—for those of us who enjoy more visually engaging comparisons—like dropping 800,000 baby grand pianos out of a very large third-story picture window.

But aside from the visceral joy of watching, what's the point of causing such a crash? First of all, the collision gouged a hole in the side of a comet the size of a football field and an estimated hundred feet deep. That gave astronomers the first-ever view beneath the surface of one of those mysterious wanderers. Maybe just as important, knowing a bit more about what's inside a comet might help humanity avoid extinction if we ever discover a comet streaking toward Earth.

Comet Tempel 1 is, by all measures, an ordinary comet, orbiting the Sun in the region between Mars and Jupiter. That was just fine with A'Hearn and his collaborators: studying a typical example from a group of objects gives more insight about the group than the extreme cases do. But examine anything closely enough, and it becomes interesting. Intensive studies of Tempel 1, done well before the impact, showed that even such an undistinguished comet is an intriguing object. Shaped like a fist, and less than five miles across at its widest, Temple 1 is covered with pits and pockmarks left by more than 4 billion years of cosmic collisions.

Comets are thought to have formed early in the solar system's history and to have undergone little geologic change since that time. Hence their internal composition should hold fossilized clues about the chemical origins of the planets. From thousands of spectroscopic observations made before and after the collision, the Deep Impact team was able to determine the relative proportions of the elements and compounds that originally made up the comet and the material ejected by the impact.

The data showed that, in the two-tenths of a second following the impact, the temperature of the impact site flashed above 2,000 degrees Fahrenheit. More than a thousand tons of material were thrown into space: cometstuff containing water vapor, carbon dioxide, cyanide gas, and an unexpectedly large amount of organic matter rich in carbon and hydrogen atoms.

But the water vapor, surprisingly, made up only a small fraction of the ejected material—not what you'd expect if, according to conventional wisdom, comets are made mostly of ice. Deep Impact's preliminary results thus seem to confirm a more recent proposal: that comets are made mostly of rock, not ice. In short, they may be "snowy dirtballs" instead of "dirty snowballs."

In one sense, *Deep Impact* did its job too well. The collision kicked up so much cometary material, which in

(Continued on page 74)

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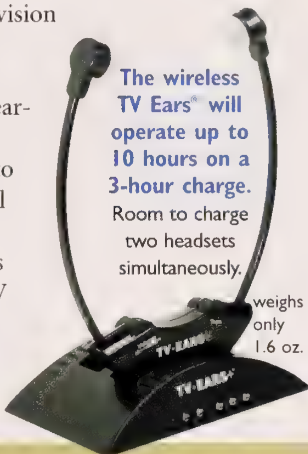

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OUT THERE

(Continued from page 70)

turn reflected so much sunlight, that the cloud of comet dust obscured the impact crater from view. By the time the cloud cleared, the *Deep Impact* mother ship had already flown too far away from the comet to get a clear look at the crater bottom. So A'Hearn and his collaborators still cannot give an exact measure of the crater's depth.

But the gigantic plume from the impact has led to another important preliminary conclusion. The internal structure of Tempel 1 is downright flimsy. The projectile from *Deep Impact* didn't hit a rock or an ice cube or even something in between. Instead it whacked into a loosely packed ball, assembled slowly out of sand and snowflakes over billions of years. The particles did not get cemented together by melting and resolidification, and apparently are barely held together by gravity.

So what? Consider this: If a killer comet bound for Earth were equally flimsy, we earthlings probably couldn't use a single powerful rocket to push or pull it off its collision course. Instead, the comet would break apart, leaving most of its deadly mass still hurtling toward our hapless home.

A few days after the historic collision, the *Deep Impact* mother ship was still fully operational. So a big question loomed: Should the trajectory of the spacecraft be adjusted to fly by Comet Tempel 1 again, in 2011, to get a fresh look at the crater after the dust has settled? After weighing the options, A'Hearn's team decided instead to aim the space probe toward another comet, 85P/Boethin, for a rendezvous in 2008. If all goes as planned, a little more than two years from now astronomers will once more get a close-up view of an icy cosmic dirtball. Since the *Deep Impact* impactor is nothing but interplanetary vapor now, though, we'll all have to do without the Fourth of July fireworks.

CHARLES LIU is a professor of astrophysics at the City University of New York and an associate with the American Museum of Natural History.

THE SKY IN APRIL

By Joe Rao

On April 8, one day after passing aphelion (its farthest point from the Sun), Mercury reaches its greatest western elongation. One might hope for good viewing, since the planet attains its greatest possible angular separation from the Sun—twenty-eight degrees. But for observers at mid-northern latitudes, that morning's apparition is the poorest of the year, because Mercury is well to the south of the Sun and hugs the eastern horizon for much of the month. On the 8th, Mercury shines at magnitude 0.3. Because the planet rises less than fifty-five minutes before the Sun, however, it is soon lost in the glare of sunrise.

Venus is the brightest morning "star" this month, but it blazes low in the east-southeast during the first light of dawn. As the sky brightens and Venus rises, the planet appears to fade and shrink. This month, it gets a little lower and less brilliant each week. On the morning of the 18th Venus has a close encounter with Uranus, the seventh planet from the Sun. With Venus as a guide, use binoculars to find a small, greenish-blue "star" just 0.3 degree below and slightly to the right of Venus. That "star" is Uranus. On the 24th Venus and the waning crescent Moon pair up in dawn's early light.

As evening twilight ends, Mars is in the western sky, nearly halfway between the horizon and zenith (the point directly overhead). This month the Red Planet continues to fade and shrink as it speeds eastward from the constellation Taurus, the bull, and into the constellation Gemini, the twins, by the 14th. Two evenings later it is midway between the orange star Aldebaran, in Taurus, and the yellow star Pollux, in Gemini. A fat crescent Moon hovers well above Mars on the evening of the 3rd.

As April begins, Jupiter rises in the east-southeast about an hour and a quarter after evening twilight. The planet is about two and a half degrees east of the star Alpha Librae. Each night, Jupiter moves a bit farther to the west; on the night of the 24th and 25th it passes one degree north of the star, the second of three conjunctions the pair has in 2006.

Saturn, in the constellation Cancer, the crab, rides high in the south-southwest as darkness falls and doesn't set until well past midnight all month. In a telescope the rings are tilted twenty degrees toward Earth. After this month, you won't see the rings tipped this far again until 2014! In fact, in three years the rings will be edge-on to our line of sight. On the evening of the 6th, Saturn is situated below a waxing gibbous Moon.

The Moon waxes to first quarter on the 5th at 8:01 A.M. and to full on the 13th at 12:40 P.M. It wanes to last quarter on the 20th at 11:28 P.M. and to new on the 27th at 3:44 P.M.

On the 1st, observers across much of eastern North America can watch as a waxing crescent Moon occults, or crosses in front of, the main body of the Pleiades star cluster, in Taurus. With binoculars or a low-power telescope, watch between about 7:20 and 9:40 P.M. as each jewel-like star in the Pleiades abruptly winks out behind the Moon's dark side and, later, suddenly reappears from behind the sunlit crescent. The Moon's dark portion will likely be dimly lit by earthshine, giving it a mottled blue-gray and yellow-white cast. For observers in the central and western states, the Moon edges just to the east of the cluster as darkness falls.

Daylight saving time returns for much of Canada and the United States on Sunday, the 2nd. Remember to "spring ahead," and set clocks forward one hour.

Unless otherwise noted, all times are given in eastern daylight time.

(Continued from page 12)

tant varieties of cotton that could minimize losses to weevils.

Starting Life

Thank you, Antonio Lazcano, for your summary of the most up-to-date information on how life began ["The Origins of Life," 2/06]. Since the seventh grade I have been curious about how life got started, and I've wondered what great advances in such knowledge would occur in my lifetime (I'm now sixty-four). I have been well satisfied with the progress so far!
Joanne R. Polner
Franklin Lakes, New Jersey

Antonio Lazcano has drawn together an excellent comprehensive summary of the many plausible physical phenomena that may have led to the beginning of life: heterotrophic theory, hydrothermal vents, Miller-Urey reactions on Earth's soupy surface, a pre-RNA world, an RNA world, and seeding from meteorites or other planets. It would be wrong, however, to conclude that, because the list is long, scientists are conflicted and that therefore life began by means of supernatural processes. The fact that there are so many plausible ways to create life from inanimate material makes it even more likely that life originated by natural means.
Fred Haag
Burnt Hills, New York

Expanding Space

I am struggling with one of Neil deGrasse Tyson's statements in "Fire and Ice" [12/05–1/06]: If the fastest known speed is that of light and other electromagnetic waves—186,000 miles per second—how could the universe expand to "about a thousand times the size of our solar system" one second after the big bang?
John Stiles
Johnston, Iowa

NEIL TYSON REPLIES: John Stiles was not the only one who wrote a letter asking this question. The cosmic speed limits imposed by relativity are specific to movement within a pre-existing space, such as what was described in Einstein's special theory of relativity. The speed of light caps the rate at which information can be communicated from one place to another.

In Einstein's general theory of relativity, the modern theory of gravity, space itself can stretch—at any speed whatsoever. Meanwhile, the speed of ordinary light and matter remains bounded by the speed of light in a vacuum.

Natural History *welcomes correspondence from readers. Letters should be sent via e-mail to* nhmag@naturalhistorymag.com *or by fax to 646-356-6511. All letters should include a daytime telephone number, and all letters may be edited for length and clarity.*

Moveable Museum Fleet Expands

Dinosaurs: Ancient Fossils, New Discoveries is the latest addition to the Museum's fleet of Moveable Museums—converted recreational vehicles outfitted as state-of-the-art, walk-in exhibition spaces. This newest Moveable complements the Museum's recent special exhibition of the same name, focusing on the latest findings in paleontology, and is made possible through the generous corporate support of Bloomberg.

Inside, the vehicle will be divided into three primary zones. "Age of Dinosaurs" will let visitors examine fossil evidence to understand what may have caused the mass extinction about 65 million years ago. "Mesozoic Mysteries" will consider questions about dinosaur diet, movement, and behavior. The final zone, "Bird-Dino Connection," will feature a diorama re-creating a 130-million-year-old prehistoric forest in what is now Liaoning Province, China.

Interactive activities, interpretive models, captivating video presentations, and numerous fossil specimens that visitors can touch ensure that the Museum's newest Moveable Museum will offer exciting learning opportunities for all ages.

All four Moveable Museums—*Dinosaurs: Ancient Fossils, New Discoveries, The Paleontology of Dinosaurs, Structures & Culture,* and *Discovering the Universe*—are free of charge and available year-round for school programs, summer programs, and community events throughout New York City. All school programs include a pre-visit teacher workshop, in-class lessons with Museum Educators, and a visit to the Moveable Museum.

For more information, please contact Kevin Orangers, Manager of the Moveable Museum Program, at 212-769-5138.

The *Dinosaurs: Ancient Fossils, New Discoveries* Moveable Museum is generously supported by Bloomberg. Founding support for the *Paleontology of Dinosaurs* Moveable Museum was provided by the children and grandchildren of Irma and Paul Milstein. Additional generous support provided by The Barker Welfare Foundation The *Structures & Culture* Moveable Museum is generously supported by Citigroup. The *Discovering the Universe* Moveable Museum is made possible through the generous support of the Charles Hayden Foundation. Additional support for the Moveable Museum program is provided by KeySpan Energy.

Center for Biodiversity and Conservation Spring Symposium

Conserving Birds in Human-Dominated Landscapes: Weaving a Common Future

Thursday and Friday, April 27 and 28
9:00 a.m. to 5:00 p.m.
Visit **www.amnh.org** for details.

Museum Shop Online

www.amnh.org

The Museum Shop is a lively marketplace of wonders that reflect the Museum's exhibitions on human cultures, the natural world, and the universe. Now, 24 hours a day, you can browse and purchase a variety of merchandise from around the world that will satisfy the curious of all ages. Purchases support the education and research endeavors of the American Museum of Natural History.

New Book on AMNH Dioramas: *Windows on Nature*

The American Museum of Natural History in partnership with Harry N. Abrams, Inc., has published the first and definitive book on the Museum's famous habitat dioramas. Titled *Windows on Nature: The Great Habitat Dioramas of the American Museum of Natural History* and authored by Stephen C. Quinn, the richly illustrated volume, available in both hardcover and softcover editions, showcases the Museum's world-renowned habitat dioramas as superb examples of art in the service of science.

The book includes full-color photographs of more than 40 featured dioramas, rarely seen historical photographs from the Museum's archives, and an informative, entertaining description of each diorama.

Readers will encounter tales of adventure and intrigue in the development and creation of individual dioramas; stories about the brilliant, passionate, and sometimes eccentric artists and naturalists who made the dioramas; eye-opening explanations of the art and technology of diorama illusion; and information about the species and locations depicted, including the role of dioramas in the conservation movement.

Also included are background on the development of dioramas as an art form, the Museum's preeminent role in the history of dioramas, the fascinating and sometimes mind-boggling techniques of diorama making, and the current state of diorama art.

Stephen C. Quinn is an artist and a naturalist and Senior Project Manager in the Department of Exhibition at the Museum.

Windows on Nature is available in Museum Shops in hardcover for $40.00, and in a special softcover edition, available exclusively at the Museum, for $27.95.

The Butterfly Conservatory

D. FINNIN/AMNH

The perennially popular *Butterfly Conservatory* has been extended and will now be on view until June 23! Visitors can stroll among up to 500 live butterflies while learning about their life cycle and conservation efforts, and, with luck, one of the spectacular tropical beauties might perch on an outstretched finger or an upturned head.

This exhibition is made possible, in part, through the generous support of JPMorgan Chase.

PEOPLE AT THE AMNH

Craig Chesek
Senior Photographer
Department of Communications

When Craig Chesek first saw an ad for a photographer specializing in shooting gems, minerals, and artifacts, he responded quickly. The job description closely fit his interests and background as a commercial photographer. But as Senior Photographer, Craig has had the opportunity to photograph much more than he signed up for.

After a decade at the Museum, Craig has photographed items as varied as the Star of India and a newly named species of bird, along with prominent figures such as Harrison Ford, Maya Angelou, and the Dalai Lama. His work has been featured in many of the Museum's exhibitions as well as Museum-related publications, including *Windows on Nature*. Over the years, he has seen the Photo Studio shift from strictly film to almost entirely digital, with all the associated challenges and advantages this transition entails. He works daily to maintain "order in the universe" of the photo archives and to service all Museum departments in need of the Studio's assistance.

While his work has brought him to several exotic and distant locales, Craig's favorite assignment was a location shoot in Mauritania, Africa, to document Museum scientists conducting field research among 900-million-year-old stromatolites, a specimen of which is now on view in the Gottesman Hall of Planet Earth.

A self-professed "two wheel junkie," Craig commutes to work daily on a bicycle, or, when he can, his motorcycle. He has motorcycled cross-country twice, totaling 19,000 miles, to visit and photograph numerous national parks.

Museum Events

AMERICAN MUSEUM OF NATURAL HISTORY

www.amnh.org

EXHIBITIONS

Darwin

Through August 20, 2006

Featuring live animals, actual fossil specimens collected by Charles Darwin, and manuscripts, this magnificent exhibition offers visitors a comprehensive, engaging exploration of the life and times of Darwin, whose discoveries launched modern biological science.

The American Museum of Natural History gratefully acknowledges **The Howard Phipps Foundation** for its leadership support. Significant support for *Darwin* has also been provided by Chris and Sharon Davis, Bill and Leslie Miller, the Austin Hearst Foundation, Jack and Susan Rudin, and Rosalind P. Walter. Additional funding provided by the Carnegie Corporation of New York, Dr. Linda K. Jacobs, and the New York Community Trust–Wallace Special Projects Fund. *Darwin* is organized by the American Museum of Natural History, New York (www.amnh.org), in collaboration with the Museum of Science, Boston; The Field Museum, Chicago; the Royal Ontario Museum, Toronto, Canada; and the Natural History Museum, London, England.

The Butterfly Conservatory

Through June 23, 2006

A return engagement of this popular exhibition includes up to 500 live, free-flying tropical butterflies in an enclosed habitat that approximates their natural environment.

This exhibition is made possible, in part, through the generous support of JPMorgan Chase.

Voices from South of the Clouds

Through July 23, 2006

China's Yunnan Province is revealed through the eyes of the indigenous people, who use photography to chronicle their culture, environment, and daily life.

The exhibition is made possible by a generous grant from Eastman Kodak Company. The presentation of this exhibition at the American Museum of Natural History is made possible by the generosity of the Arthur Ross Foundation.

Vital Variety

Ongoing

Beautiful close-up photographs highlight the diversity of invertebrates.

LECTURES

76th Annual James Arthur Lecture: Are Human Brains Unique?

Monday, 4/3, 6:00 p.m.

Michael Gazzaniga, Sage Center for the Study of Mind, University of California, Santa Barbara, will discuss his research on the mysteries of the human brain.

Art/Sci Collision: Brandon Ballengée

Thursday, 4/20, 7:00 p.m.

The art projects and installations created by Brandon Ballengée are scientific collaborations meant to engage the public in the broader discussion of environmental issues.

The First Human

Tuesday, 4/25, 7:00 p.m.

Ann Gibbons will talk about the race to find the "missing link" and her book, *The First Human: The Race to Discover Our Earliest Ancestors.*

The 2006 Mack Lipkin Man and Nature Lecture: Biodiversity and the Evolutionary Roots of Beauty

Thursday, 4/27, 7:00 p.m.

Renowned ecologist Gordon Orians delves into the intricate relationship between humans and nature.

FIELD TRIPS & WORKSHOPS

Spring Bird Walks in Central Park

Four series of eight weekly walks begin *Tuesday, April 4.* With naturalists Stephen C. Quinn, Joseph DiConstanzo, and Harold Feinberg.

Animal Drawing

Eight Thursdays, 4/6–5/25 7:00–9:00 p.m.

Learn about the gifted artists who created the world-class dioramas as you sketch subjects in their "natural" environments with Stephen C. Quinn.

FAMILY AND CHILDREN'S PROGRAMS

Science in the Galápagos: Bird Adaptations

Sunday, 4/2, 11:00 a.m.–12:00 noon and 1:00–2:00 p.m. (Ages 5–7, each child with one adult)

Join science educator Amy O'Donnell for an introduction to some of the plants and animals of the Galápagos.

Observing Worms

Sunday, 4/30, 11:00 a.m.–12:30 p.m.

In this hands-on workshop with Museum biologist Elizabeth Nichols, observe live worms and learn how they transform the soil.

New! Cosmic Collisions

Wednesday, 4/5, 4:00–5:30 p.m.

See the new Space Show, *Cosmic Collisions*, and follow up with an in-depth workshop exploring the science behind the show.

New! Cosmic Splat!

Sunday, 4/9, 11:00 a.m.–12:30 p.m. (Ages 4–5, each child with one adult) and 1:30–3:00 p.m. (Ages 6–7, each child with one adult)

In this hands-on workshop, explore the forces that drive the universe.

Space Explorers: Behind the Scenes of *Cosmic Collisions*

Tuesday, 4/11, 4:30–5:30 p.m. (Ages 10 and up)

ZHOA JIHUA (45-YEAR-OLD BAI WOMAN), SANSHE VILLAGE/PHOTOVOICE

Old women chatting

STARRY NIGHTS
Live Jazz

ROSE CENTER FOR EARTH AND SPACE

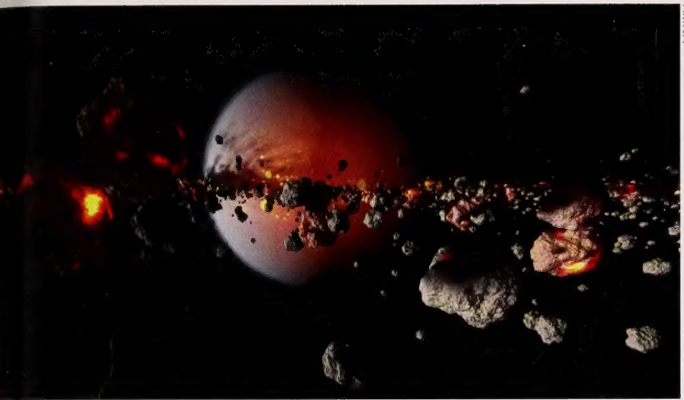
6:00 and 7:30 p.m.

Friday, April 7

HoJo5

The 7:30 p.m. set will be broadcast live on WBGO Jazz 88.3 FM.

Starry Nights is made possible, in part, by Constellation NewEnergy and Fidelity Investments.



AMNH

Artist's conception of the formation of our Moon from the new Space Show *Cosmic Collisions*

On the second Tuesday of each month, kids (and their parents) can learn under the stars of the Hayden Planetarium.

Dr. Nebula's Laboratory: Wind and Water
Sunday, 4/23, 2:00–3:00 p.m.
A storm is brewing in Dr. Nebula's lab! Join Scooter for a whirlwind adventure as she dodges tornadoes and other forces of nature.

AMNH SPRING CAMPS
Monday–Friday, 4/17–4/21
9:00 a.m.–4:00 p.m.

New! **Meet the Beetles: Darwin Adventures**
(For 2nd and 3rd graders)

Destination Space: Stars and Light
(For 4th and 5th graders)

HAYDEN PLANETARIUM PROGRAMS

TUESDAYS IN THE DOME
Virtual Universe
Out of This Galaxy
Tuesday, 4/4, 6:30–7:30 p.m.

This Just In...
April's Hot Topics
Tuesday, 4/18, 6:30–7:30 p.m.

Celestial Highlights
Of Myths and Maps
Tuesday, 4/25, 6:30–7:30 p.m.

HAYDEN PLANETARIUM SHOWS

Cosmic Collisions
Journey into deep space—well beyond the calm face of the night sky—to explore cosmic collisions, hypersonic impacts that drive the dynamic formation of our universe. Narrated by Robert Redford.

Cosmic Collisions was developed in collaboration with the Denver Museum of Nature & Science; GOTO, Inc., Tokyo, Japan; and the Shanghai Science and Technology Museum.
Made possible through the generous support of CIT.
Cosmic Collisions was created by the American Museum of Natural History with the major support and partnership of the National Aeronautics and Space Administration's Science Mission Directorate, Heliophysics Division.

SonicVision
Fridays and Saturdays, 7:30 and 8:30 p.m.
Hypnotic visuals and rhythms take viewers on a ride through fantastical dreamspace.

SonicVision is made possible by generous sponsorship and technology support from Sun Microsystems, Inc.

LARGE-FORMAT FILMS

LeFrak IMAX Theater
Galápagos explores the unique fauna of the islands and the surrounding sea.

IMAX films at the Museum are made possible by Con Edison.

INFORMATION

Call 212-769-5100 or visit www.amnh.org.

TICKETS AND REGISTRATION

Call 212-769-5200, Monday–Friday, 9:00 a.m.–5:00 p.m., or visit www.amnh.org. A service charge may apply.
All programs are subject to change.

AMNH eNotes delivers the latest information on Museum programs and events to you monthly via email. Visit www.amnh.org to sign up today!

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- Discounts in the Museum Shops and restaurants and on program tickets
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- Invitations to Members-only special events, parties, and exhibition previews

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Wild Przewalski's horses graze in the exclusion zone around Chernobyl.

ENDPAPER

Chernobyl Paradox

By Mary Mycio

Twenty years ago, on April 26, 1986, a reactor at the Chernobyl nuclear power station exploded and burned, spewing radiation around the globe and blanketing large swaths of what was then the Soviet Union with heavy contamination. Ever since that day, the word "Chernobyl" has become a synonym for "horrific disaster," conjuring the lifeless radioactive deserts of Atomic Age sci fi.

Whenever I thought about the irradiated land fifty miles north of Kiev, it always seemed the last place on Earth to go for the study of natural history. Natural history is about life—what plants and animals do. But wouldn't a search for life in such a dead zone be, at best, oxymoronic? Surely, one would do better studying the natural history of a parking lot.

What I found at Chernobyl instead was an astonishing new ecosystem that defied my gloomy imaginings. The evacuation of more than 300,000 people from an "exclusion zone" surrounding the reactor was a traumatic interruption of their lives. But the ban on human habitation and activities has enabled an area of 1,800 square miles—almost double the size of Rhode Island, or half a Yellowstone Park—to come back to life. Today Chernobyl is Europe's largest nature sanctuary, with rebounding populations of deer, moose, and wild boar.

During more than twenty visits to the zone, I've seen wolves in broad daylight, heard the call of an endangered lynx at nightfall, and spent hours communing with a herd of rare Przewalski's horses that were experimentally released into the wild there. Like their habitat, they are radioactive—cesium-137 packs into their muscles and strontium-90 into their bones. But to nearly everyone's surprise, they are also thriving.

The international border between Belarus and Ukraine cuts the exclusion zone into two roughly equal regions, but the border is meaningless to wildlife. When a lone brown bear (one of the few species not to have made a Chernobyl comeback) wandered from one region to another, the Ukrainians thought it came from Belarus, and the Belarusians thought it came from Ukraine. As for the bear, it disappeared, with no hint of its origins or clue to its destination.

Of course, birds, too, are indifferent to borders. In February migrating swans infected with avian flu virus arrived in western Europe from an unusually frigid Ukraine and Russia. But birds are not indifferent when it comes to choosing between places where people live and places where they don't. As many as 280 species of birds have appeared around Chernobyl, including such rare species as black storks and aquatic warblers.

Birds that nest in places highly contaminated with strontium-90 can suffer. The isotope mimics calcium and accumulates in eggshells, bombarding embryos with beta particles. Some species, such as barn swallows, have depressed fertility. But for now, at least, the benefits of the human-free habitat seem to outweigh the untoward effects of radiation.

My most memorable encounter with Chernobyl birds was in Belarus, which is restoring some peat mires that the Soviet Union drained for farming. The area is one of the most contaminated places in the country—and on the planet. But the contamination is mostly cesium-137, which doesn't accumulate in eggshells, rather than strontium-90, which does.

When my guide and I arrived, dozens of black storks pierced the air above our van with their red beaks. Thousands of ducks took off in a tornadolike cloud. A blur of mute swans, grey herons, and great white egrets flew deep into the reflooded peat mires.

"It's so beautiful," I murmured.

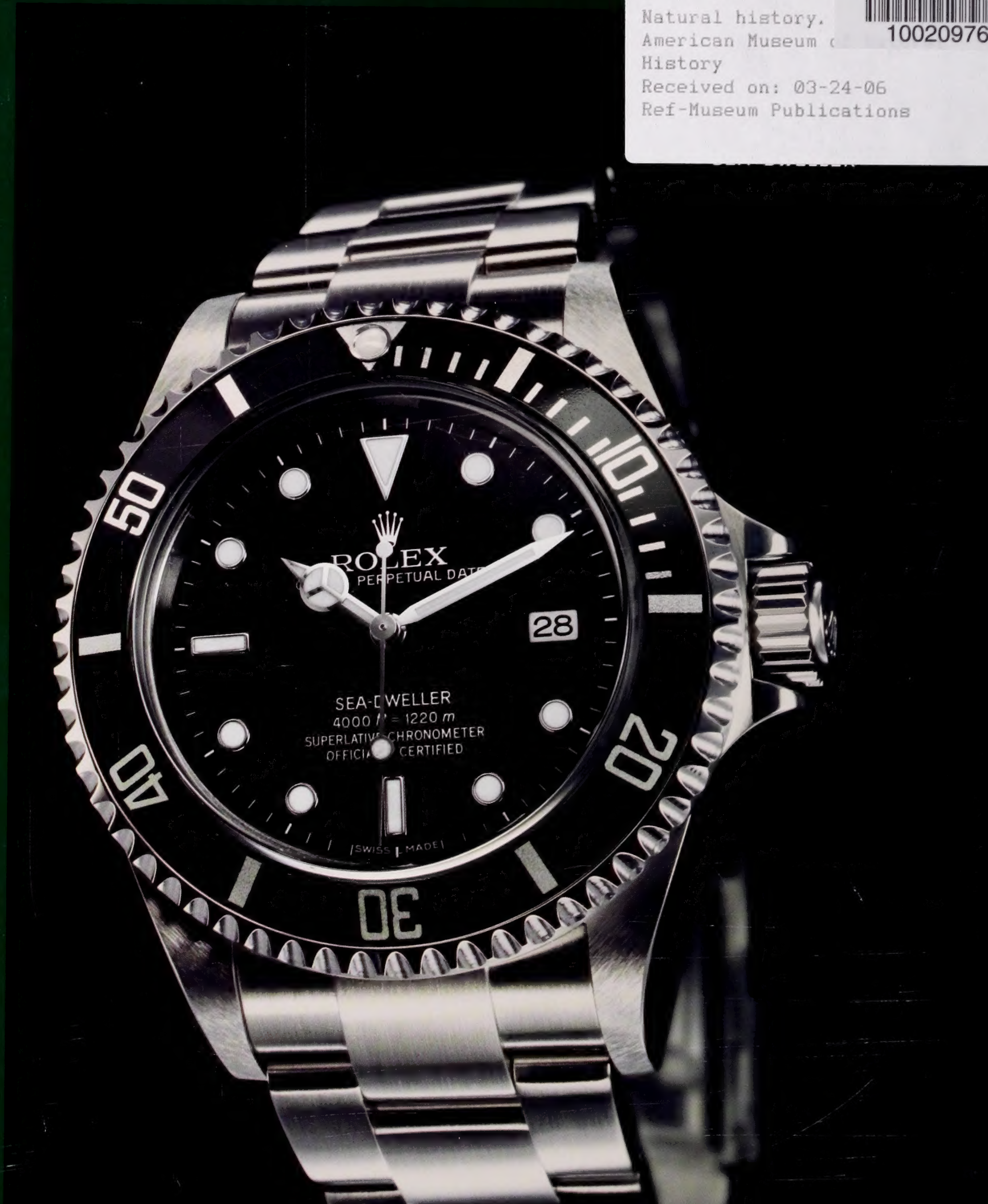
"And radioactive," said my guide.

"If it weren't radioactive," I replied, "it would be a farm, and there would be no birds."

It is Chernobyl's most profound paradox. The worst nuclear disaster in history wreaked havoc with people's lives and rendered a vast territory uninhabitable.

But in the absence of humans, Chernobyl's wildlife is not just doing fine. It is flourishing, beautiful—and radioactive.

MARY MYCIO is an American writer living and working in Ukraine. She is the author of Wormwood Forest: A Natural History of Chernobyl *(Joseph Henry Press, 2005). Visit* www.chernobyl.in.ua *to view a gallery of photographs and read excerpts from her book.*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